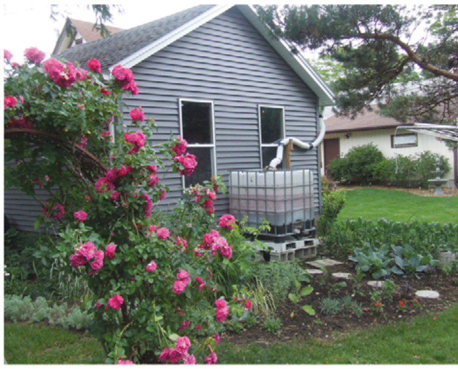
July 2008

Managing Stormwater in Your Community

A Guide for Building an Effective Post-Construction Program



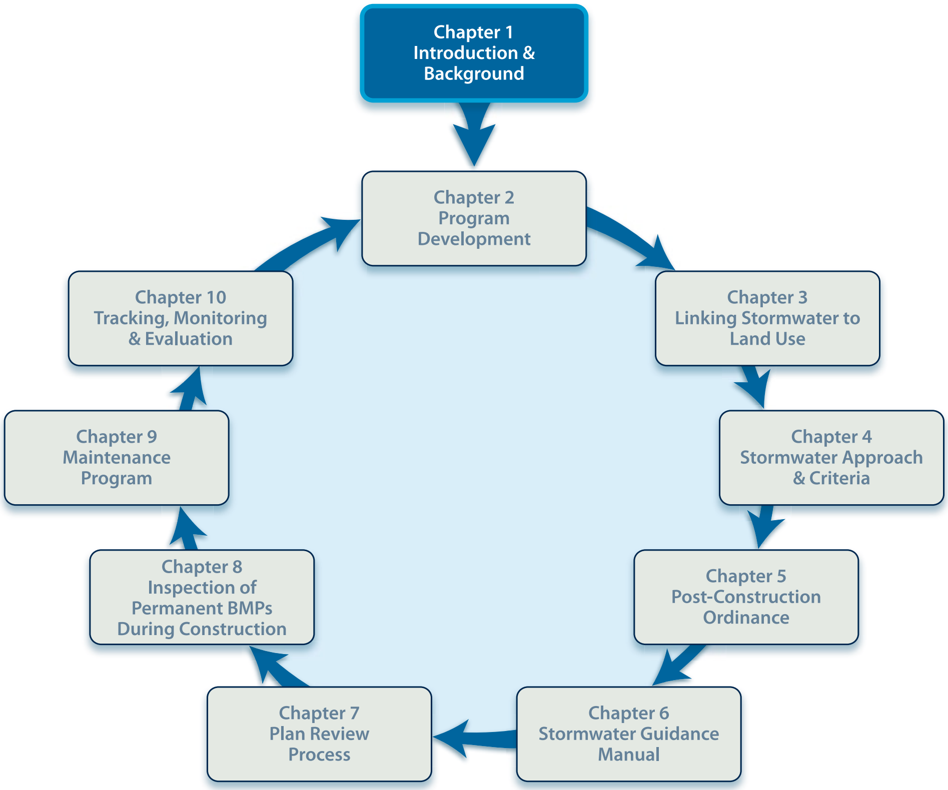



Center for Watershed Protection

EPA Publication No: 833-R-08-001

Chapter 1

Introduction and Background



What's In This Chapter

- Post-Construction Stormwater Basics and the Guidance Manual
- Relationship of Post-Construction Stormwater Management to:
  - Construction Stormwater Management
  - Impaired Waters (TMDLs)
  - Combined Sewer Overflows
  - Stormwater Retrofitting
- Regulatory Background
- Current Trends and Recommendations for Post-Construction Stormwater Management

Download Post-Construction Tools at:
www.cwp.org/postconstruction

1.1. Introduction

Communities across the country are increasingly viewing stormwater management as an opportunity to improve the environment, create attractive public and private spaces, engage the community in environmental stewardship, and remedy the ills of the past, when development took place with inadequate stormwater controls.

While stormwater management has enjoyed a higher profile in recent times, communities across the country are striving to build the programmatic capabilities to effectively manage stormwater and meet regulatory requirements, such as Phases I and II of the National Pollutant Discharge Elimination System (NPDES) municipal stormwater permit program.

Many local programs have a strong emphasis on the stormwater basics of providing flood control and adequate drainage. Recently, many stormwater programs have become more sophisticated and "greener" by incorporating channel protection, groundwater recharge, protection of sensitive receiving waters, control of the overall volume of stormwater runoff, and use of natural systems and site design techniques to control runoff.

Water quality impacts from urban runoff can be significant. Many streams, lakes, and estuaries in urban areas are impaired due to urban runoff (***http://iaspub.epa.gov/waters10/attains_nation_cy.control***). Impervious surfaces, disturbed soils, and managed turf associated with urban development can have multiple impacts on water quality and aquatic life. These impacts are summarized in **Table 1.1**.

Urban development can also impact the post-development hydrograph discharging to urban streams (**Figure 1.1**). Compared to the pre-development condition, post-development stormwater discharges can increase the runoff volume, increase the peak discharge, and decrease the infiltration of stormwater, which thereby decreases baseflow in headwater streams. These changes to stream hydrology result in negative impacts on channel stability and the health of aquatic biological communities. Common problems include bank scouring and erosion, increased downstream flooding, and loss of in-stream habitat for macroinvertebrates, fish, and other organisms.

Table 1.1. Summary of Development Impacts on Water Resources

Increases in:	Decreases in:
Impervious cover, compacted soils, managed turf, and other land covers that contribute pollutants	Health and safety of receiving waters
Stormwater volume	Groundwater recharge
Stormwater velocity	Stream channel stability
Pollutant loads	Health, safety, and integrity of water supplies, reservoirs, streams, and biological communities
Stream channel erosion	Stream habitat

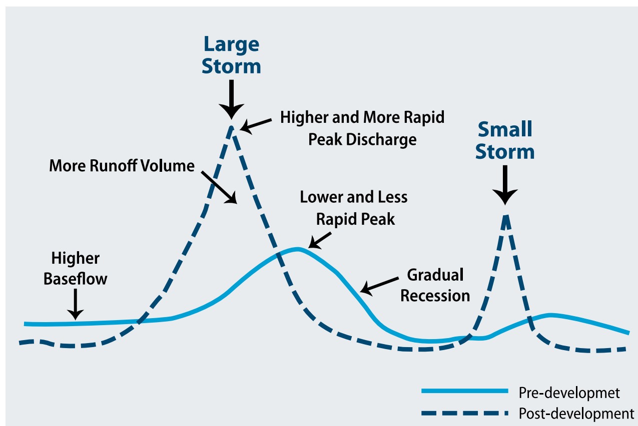


Figure 1.1. Urban development increases runoff volume, peak discharge, and time to peak

Purpose and Audience for this Guide

This guide is intended for Phase II NPDES Municipal Separate Storm Sewer System (MS4) communities (which are required to establish a post-construction program), as well as other smaller unpermitted MS4s that are interested in protecting local water resources. Other entities responsible for implementing post construction controls, such as military bases, transportation departments, and school districts, will also find this guide useful. Stormwater Phase I and other communities already implementing a post-construction program could benefit from the program assessment described in **Section 2.2** and other sections of the guide to help them identify key areas for improvement.

Finally, this guide is intended for multiple audiences within a local government. The guide recognizes the important link between overall comprehensive land use planning and the more technical components of a stormwater program. Often, land use planners and stormwater managers do not collaborate on large-scale land use and development issues. However, the activities of both groups have a profound impact on the health of watersheds and receiving waters. The guide, and especially **Chapter 3**, is meant to bridge this gap and promote a stronger link.

What's in the Guide

The guide contains chapters that address key elements of a post-construction program, and also several companion "tools." The tools are designed to be downloaded and adapted by local programs to help build program capabilities. The chapters and tools in the guide are listed in **Table 1.2**. **Figure 1.2** portrays the chapters of the guide in graphical format, showing the cyclical or iterative nature of the various program elements.

Table 1.2. Contents of Post-Construction Guidance Manual

Chapters	Description
Chapter 1 Introduction and Background	Introduces the contents of the guide and related tools. Provides a brief regulatory background on post-construction stormwater management.
Chapter 2 Post-Construction Program Development	Provides the stormwater manager with an understanding of the community and watershed components of a stormwater plan and introduces a program self-assessment tool. *Companion to Tool 1: Self-Assessment and Tool 2: Program and Budget Planning Tool*
Chapter 3 Land Use Planning as the First BMP: Linking Stormwater to Planning	Examines the link between stormwater and land use planning. Details how to build a more effective program through integrated stormwater and planning tools. *Companion to Tool 4: Codes and Ordinance Worksheet*
Chapter 4 Developing a Stormwater Management Approach and Criteria	Introduces a recommended stormwater management approach and how to distill this approach into criteria for a stormwater ordinance and guidance manual. *Companion to Tool 5: Manual Builder*
Chapter 5 Developing a Post-Construction Stormwater Ordinance	Works through the nuts and bolts of building a stormwater ordinance and illustrates major decision points. *Companion to Tool 3: Model Ordinance*
Chapter 6 Developing a Stormwater Guidance Manual	Reviews stormwater policy and design guidance from A to Z. Includes tips for building a manual that best suits the community. *Companion to Tool 5: Manual Builder*
Chapter 7 The Stormwater Plan Review Process	Delves into the anatomy of a good review process and how to use it to ensure good BMP design and long-term maintenance. *Companion to Tool 6: Checklists*
Chapter 8 Inspection of Post-Construction BMPs during Construction	Offers guidance on the process for initial installation of post-construction BMPs during the construction phase. *Companion to Tool 6: Checklists and Tool 7: Performance Bonds*

Table 1.2. Contents of Post-Construction Guidance Manual *(continued)*

Chapters	Description
Chapter 9 Developing a Maintenance Program	Explores three models for a maintenance program and provides tips for an effective program. *Companion to Tool 5: Manual Builder, Tool 6: Checklists and Tool 7: Performance Bonds*
Chapter 10 Tracking, Monitoring, and Evaluation	Reviews the development of measurable goals and milestones. Provides guidance on program evaluation, annual reports, and preparing for a possible program audit. *Companion to Tool 8: BMP Evaluation Tool*
Tools	**Description**
Tool 1 Post-Construction Stormwater Program Self-assessment	Evaluates the current status of the program, and where it needs to go. This checklist tool can be used to set short- and long-term goals.
Tool 2 Program and Budget Planning Tool	Provides planning milestones and assists with development of planning-level budget figures using a spreadsheet.
Tool 3 Post-Construction Stormwater Model Ordinance	Provides model language to build or enhance the ordinance. Language is keyed to three levels of program sophistication.
Tool 4 Codes and Ordinance Worksheet	Assesses zoning, subdivision, and other codes in the context of impervious cover creation and ability to promote effective stormwater management through design.
Tool 5 Manual Builder	Provides links to the best design and program resources around the country. Useful for stormwater managers who are developing a manual or adapting an existing manual.
Tool 6 Checklists	Provides detailed checklists for plan review, best management practice (BMP) installation during construction, and maintenance. The checklists address both structural and nonstructural stormwater BMPs.
Tool 7 Performance Bond Tool	Supplies templates that can be adapted to develop a performance bond for the program—an effective tool to ensure good BMP installation.
Tool 8 BMP Evaluation Tool	Asks the right questions when it comes to verifying the performance of various BMPs, especially proprietary devices.

Download Tools at: ***www.cwp.org/postconstruction***

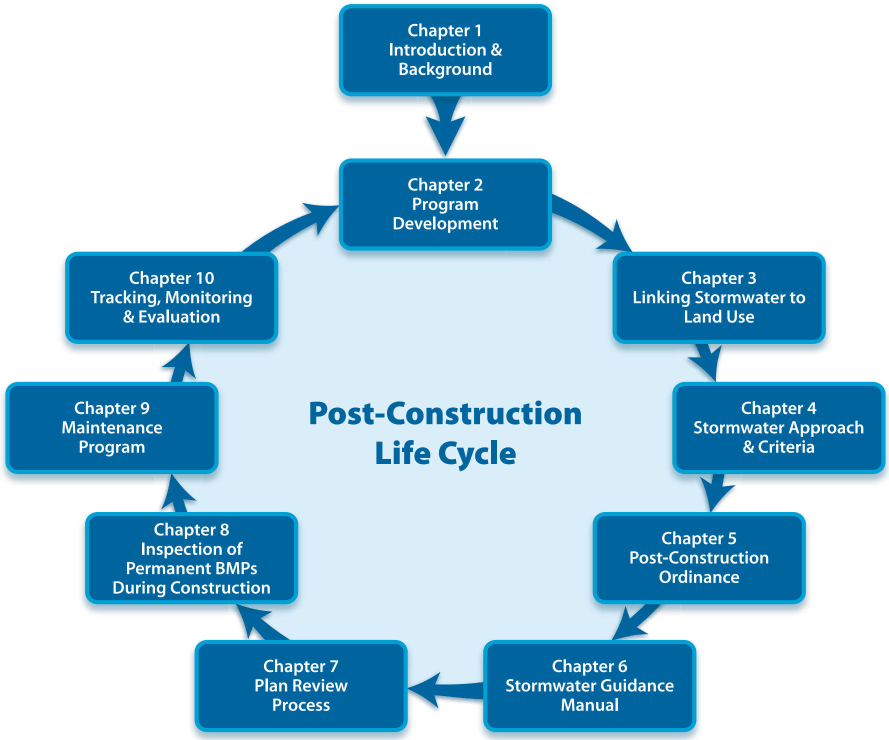


Figure 1.2. **The Post-Construction Stormwater Life-Cycle, as presented in this guide. The program elements are presented in a cyclical or iterative format, as programs evolve.**

1.2. Relationship of Post-Construction to Construction Stormwater (Erosion and Sediment Control)

This guide addresses runoff from projects after the construction phase is complete. Stormwater runoff from projects during active construction is typically addressed through requirements for stormwater pollution prevention plans (SWPPPs) and erosion and sediment control BMPs. Guidance on developing SWPPPs for construction projects is available from EPA (see *Developing Your Stormwater Pollution Prevention Plan: A Guide for Construction Sites* at ***http://www.epa.gov/npdes/swpppguide***).

A local program must carefully consider the relationship between construction and post-construction stormwater. Construction stormwater BMPs listed in a SWPPP are designed to minimize impacts during the active construction phase, and they do not always translate into BMPs applicable for post-construction. Post-construction BMPs must treat runoff from the newly constructed or redeveloped site, including runoff from roads, parking lots, yards, rooftops, and other land uses associated with development.

In some cases, construction and post-construction BMPs can be located in the same area, such as a sediment control basin or trap converted to a permanent stormwater BMP. Colocating construction and post-construction BMPs can help a designer follow natural drainage patterns, can be an economical approach, and often works when proper construction sequencing and standards are followed (see **Table 1.3** for more details).

However, increasingly, it is being found that construction and post-construction BMPs should be located on different parts of the site and have different sizing and design criteria. For instance, post-construction BMPs might involve practices distributed across the site, such as bioretention and infiltration practices. In this case, the post-construction BMP locations must be carefully protected during the construction phase in order to preserve the soil structure necessary for long-term BMP effectiveness. Also, the post-construction BMPs must be installed in the proper construction sequence—***after*** contributing drainage areas are stabilized—in order to prevent construction sediment runoff from clogging the newly installed bioretention or infiltration practices. **Figure 1.3** portrays typical coordination needs between construction and post-construction stormwater planning.

Table 1.3 notes several other dos and don'ts with regard to coordinating construction and post-construction BMPs.

Table 1.3. Coordination Between Construction and Post-Construction Stormwater

DO:

- Coordinate plan review for construction and post-construction BMPs.
- Make sure the Limits of Disturbance (LODs) for the SWPPP (construction stormwater plan) are coordinated with natural areas and open-space areas that are supposed to be protected per the post-construction plan.
- Make sure that areas designated for post-construction BMPs are protected from disturbance and compaction during construction and are noted in the SWPPP. This is especially true for infiltration and bioretention practices that depend on an undisturbed soil structure.
- Colocate construction and post-construction BMPs where it makes sense and won't compromise the integrity of post-construction BMPs. Good candidates for colocation include:
  - Basins that will be converted from construction to post-construction configurations by dredging construction sediments and modifying outlet structures
  - Sediment traps that will be converted to bioretention/filtration (or another BMP) when, after drainage areas are stabilized, construction sediments are removed and the basin floor is excavated to a deeper layer (below the original sediment trap invert) with good soils for infiltration
  - Other cases where the local program staff can ensure the integrity of the post-construction BMPs
  - Care should especially be taken with infiltration facilities to avoid conflicts between construction and post-construction BMPs and compaction of soils.
- Make sure that inspectors and contractors are aware of both construction and post-construction BMPs to be installed at a site.

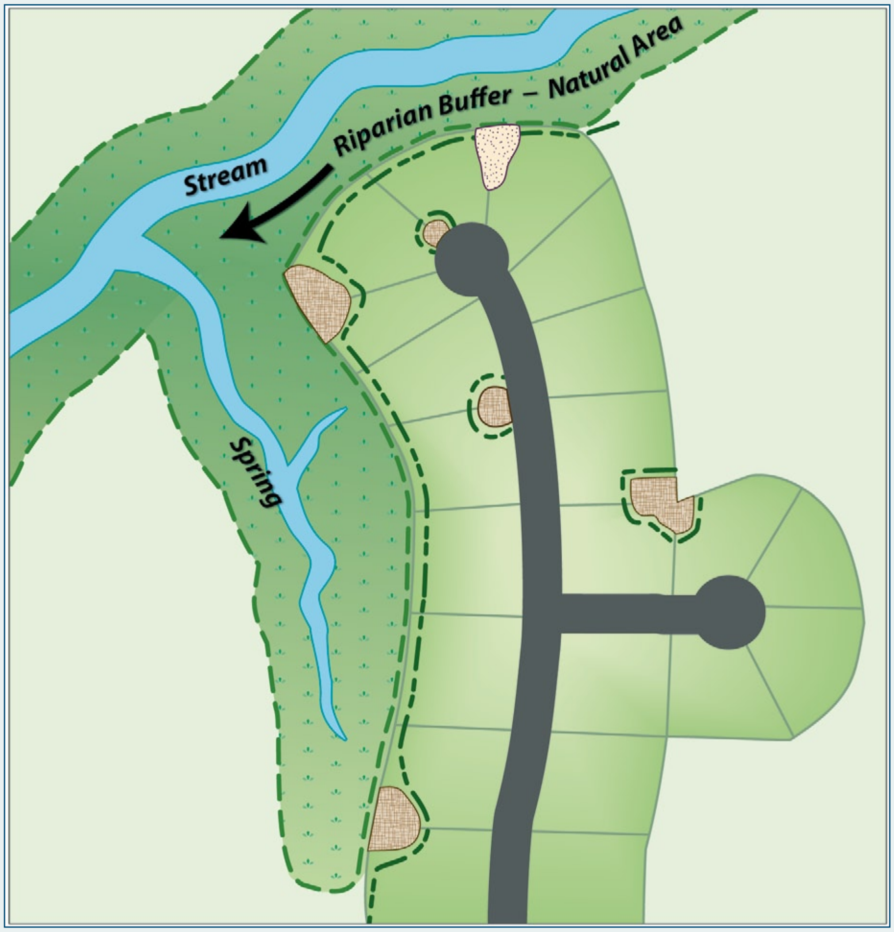
DON'T:

- Approve a SWPPP that conflicts with a post-construction stormwater plan in terms of protection of natural areas, tree protection, limits of disturbance, etc.
- Colocate construction and post-construction BMPs where soil compaction and sedimentation will damage the integrity of the post-construction BMP.
- Suspend inspections or release performance bonds until the post-constructions BMPs have been installed correctly.

1.3. Relationship of Post-Construction to Impaired Waters (TMDLs)

Under the authority of section 303(d) of the Clean Water Act, waterbodies that do not meet water quality standards are considered "impaired" and a "Total Maximum Daily Load" (TMDL) study must be conducted. This study computes the pollutant load that a waterbody can receive and still meet water quality standards, and it allocates this load to various point and nonpoint sources. Authorized states and tribes administer the TMDL program.

Currently, thousands of impaired waters are listed on state 303(d) lists. The most common sources of impairment associated with stormwater include sediment, pathogens (bacteria), nutrients, and metals (**USEPA, 2007**). Stormwater and urban and suburban runoff are significant contributors to impairments nationwide and the leading cause of impairments within some regions (**USEPA Region 5, 2007**). For this reason, EPA and relevant state agencies are increasingly motivated to create a stronger link between TMDLs and stormwater permits, such as MS4, construction site, and industrial permits. Future rounds of MS4 permit coverage will seek more targeted and/or stringent stormwater controls for impaired watersheds within the jurisdiction of MS4s.



Riparian buffer/natural area boundary

Colocated construction-phase sediment basin and post-construction BMP.

Post-construction bioretention/infiltration area — Soil must be protected during construction. Do ***not*** use for construction-phase BMPs *unless specific conditions are met (Table 1.3)*.

Limits of Disturbance (LOD) for construction-phase SWPPP — Must protect riparian buffer and post-construction infiltration area. Fencing recommended.

Figure 1.3. Construction stormwater and post-construction stormwater plans must be coordinated to protect post-construction design features and BMPs

For the local stormwater manager, this will require an effort to tailor certain stormwater criteria and BMPs to help meet TMDL pollutant-reduction benchmarks. **Chapter 4** (**Table 4.17**) provides more detail on creating a stronger link between stormwater criteria and TMDLs.

1.4. Relationship of Post-Construction to Combined Sewer Overflows (CSOs)

Many communities in the past built combined sewer systems that collect both stormwater runoff and sanitary sewage in the same pipe to be carried to a wastewater treatment plant. Wet weather events can sometimes cause these combined sewer systems to exceed their hydraulic capacity, resulting in combined sewer overflows (CSOs). A CSO can result in untreated human and industrial waste, toxic materials, and debris being discharged to receiving waterbodies, impacting water quality and aquatic habitat. CSOs cause beach closings, shellfishing restrictions, and other waterbody impairments. Combined sewer systems serve roughly 772 communities containing about 40 million people. (See EPA's NPDES Web site, accessed November 2007: ***www.epa.gov/npdes/cso***)

EPA's Combined Sewer Overflow Control Policy is the national framework for the control of CSOs through the NPDES permitting program (***www.epa.gov/npdes/pubs/owm0111.pdf***). The Policy includes a set of Nine Minimum Control Measures designed to address the causes of CSOs and limit their occurrence:

1. Monitoring to effectively characterize impacts from CSO discharges
2. Proper operation and maintenance programs
3. Maximum use of the collection system for storage
4. Review and modification of pretreatment programs
5. Maximizing flows to the wastewater treatment plant
6. Prohibiting dry weather CSO discharges
7. Control of solids and floatable materials
8. Pollution prevention programs
9. Public notification

Many of the measures required for CSO control can be directly related to post-construction stormwater management. For instance, the volume and frequency of CSO events can be reduced by implementing stormwater management practices that reduce the volume and rates of runoff. Treatment of stormwater runoff before it enters the combined sewer system also reduces the level of pollutants potentially discharged in an overflow event. Pollution prevention programs focused on reducing the exposure of pollutants to runoff entering a combined sewer system also help eliminate excess nutrients and other pollutants.

1.5. Relationship of Post-Construction to Stormwater Retrofitting

Stormwater retrofitting refers to a series of techniques that help to restore watersheds by providing stormwater treatment in locations where practices previously did not exist or were ineffective. Stormwater retrofits are typically installed at older, existing stormwater facilities, within the conveyance system, above or below outfalls, at stormwater hotspots, and at other locations that are close to the source of runoff. The intent is to capture and treat stormwater runoff ***before*** it is delivered to the receiving waters (**Schueler et al. 2007**).

Retrofitting spans the regulatory and non-regulatory sides of post-construction stormwater management:

- In a *regulatory* sense, the MS4 requirements pertain to new development and redevelopment projects. Redevelopment cases, in particular, are places where retrofitting can play a major role. For instance, existing stormwater facilities and/or conveyance systems can be retrofitted to provide better water quality treatment.
- In the *non-regulatory* context, retrofitting is a critical tool to help achieve watershed restoration goals, especially in watersheds where much of the development took place prior to modern stormwater management. For these communities, a retrofit program can be built into the overall post-construction program to help fulfill MS4 commitments.

When tailored to a community's watershed needs, retrofitting can help meet multiple objectives. For instance, a retrofitting program can reduce runoff volumes in combined sewer systems; help reduce the amount of trash and floatables reaching waterbodies; support downstream stream restoration projects; help solve existing flooding, erosion, and water quality problems; and provide key demonstration and outreach projects (Schueler et al. 2007).

Table 1.4 lists several ideas for how retrofitting can be integrated with the six minimum measures in the Phase II MS4 program.

To assist communities with a retrofitting program, the Center for Watershed Protection has produced a comprehensive guidance manual on stormwater retrofitting:

Urban Stormwater Retrofit Practices, Version 1.0, Urban Subwatershed Restoration Manual Series, Manual 3 (August 2007). ***www.cwp.org*** > Resources > Controlling Runoff & Discharges > Stormwater Management > National/Regional Guidance.

Table 1.4. Integrating Stormwater Retrofitting with the Six Minimum Measures

Minimum Measure	How Retrofitting Can Help
1. Public Education and Outreach	► Use high-visibility public sites for retrofit projects and include educational signage and interpretation. ► Use retrofit demonstration sites for outdoor classrooms, educational events, and field trips.
2. Public Participation and Involvement	► Get citizen advisory committees involved in establishing retrofit objectives and candidate locations. ► Use volunteer labor to help with retrofit project light construction, planting, mulching, and maintenance.
3. Illicit Discharge Detection and Elimination	► Use the retrofit field reconnaissance process to look for illicit discharges.
4. Construction Site Runoff Control	► Use retrofit projects to demonstrate proper erosion and sediment control to the development community. ► Look for construction sites during the retrofit field reconnaissance process, and conduct follow-up inspections.
5. Post-Construction Runoff Control	► Establish retrofitting protocols for redevelopment sites. ► In some cases, have a developer do an on-site or off-site retrofit to satisfy post-construction requirements. ► In some cases, collect a fee-in-lieu payment from a developer to help pay for strategic retrofits in the watershed. ► Build retrofitting into the facilities planning, capital improvements, and facilities maintenance program.
6. Pollution Prevention and Good Housekeeping	► Include pollution prevention and landscape stewardship projects in the retrofit program. Start with public sites, such as schools, parks, and public works yards, and incorporate findings into ongoing maintenance activities. ► Look for opportunities to retrofit water quality treatment at municipal stormwater hotspots, such as vehicle maintenance, fueling, public works, and grounds maintenance facilities. ► Use stormwater retrofit projects to set a good example for the development community and public.

1.6. Regulatory Background for Post-Construction Stormwater

Both Phase I and Phase II of the NPDES stormwater program require municipalities to develop and implement programs to address stormwater runoff from areas of new development and redevelopment (i.e., post-construction runoff). The Phase I post-construction requirements are at 40 CFR Part 122.26(d). There are approximately 1,000 Phase 1 permittees across the country (**U.S. GAO, 2007**).

The stormwater Phase II post-construction requirements are at 40 CFR 122.34(b)(5) and listed in **Table 1.5**. Because the Phase II regulations apply to smaller communities, there are many more of them, currently numbering over 5,000 nationally (**U.S. GAO, 2007**). Additionally, nontraditional MS4s in urbanized areas such as military bases, public universities, and other governmental facilities are also regulated under Phase II.

Authorized states and EPA regions use these Phase I and Phase II regulations as the basis for developing permit requirements for MS4s. The NPDES MS4 permits provide more detailed requirements that MS4s must meet. In response to these permit requirements, MS4s develop detailed plans (often called Stormwater Management Plans) that describe the activities and milestones that the MS4 will meet over the five-year permit term.

Some states also have developed post-construction standards and/or stormwater guidance manuals to implement the stormwater regulations. **Tool 5: Manual Builder** includes information on many state stormwater manuals and their associated Web sites.

The NPDES MS4 requirements are one of the various federal, state, and local regulations and programs that influence stormwater management and land development practices. **Table 1.6** lists other drivers that have some connection to stormwater management. A local program must understand this complex regulatory environment to avoid conflicts and build a sustainable program. Legal issues, such as court rulings involving negligence and nuisance, can also drive the implementation of stormwater management at the local and state levels.

1.7. Current Trends and Recommendations for Post-Construction Stormwater Management

The Center for Watershed Protection recently conducted research that canvassed local government stormwater professionals across the country (**CWP, 2006**). Respondents provided local information and insights on a range of post-construction issues. Almost 100 different local governments across 30 states responded, and the vast majority of respondents were from Phase II communities.

Table 1.7 provides a summary of the current status and trends in post-construction stormwater management based on this research. The table also lists recommended actions and references the appropriate chapters of this guide for more detailed information.

Table 1.5. EPA Stormwater Phase II Minimum Measure for Post-Construction Stormwater Management in New Development and Redevelopment (40 CFR 122.34(b)(5))

(i) You must develop, implement, and enforce a program to address stormwater runoff from new development and redevelopment projects that disturb greater than or equal to one acre, including projects less than one acre that are part of a larger common plan of development or sale, that discharge into your small MS4. Your program must ensure that controls are in place that would prevent or minimize water quality impacts.
(ii) You must: (A) Develop and implement strategies which include a combination of structural and/or non-structural best management practices (BMPs) appropriate for your community; (B) Use an ordinance or other regulatory mechanism to address post-construction runoff from new development and redevelopment projects to the extent allowable under State, Tribal or local law; and (C) Ensure adequate long-term operation and maintenance of BMPs.
(iii) Guidance: If water quality impacts are considered from the beginning stages of a project, new development and potentially redevelopment provide more opportunities for water quality protection. EPA recommends that the BMPs chosen: be appropriate for the local community; minimize water quality impacts; and attempt to maintain pre-development runoff conditions. In choosing appropriate BMPs, EPA encourages you to participate in locally-based watershed planning efforts which attempt to involve a diverse group of stakeholders including interested citizens. When developing a program that is consistent with this measure's intent, EPA recommends that you adopt a planning process that identifies the municipality's program goals (e.g., minimize water quality impacts resulting from post-construction runoff from new development and redevelopment), implementation strategies (e.g., adopt a combination of structural and/or non-structural BMPs), operation and maintenance policies and procedures, and enforcement procedures. In developing your program, you should consider assessing existing ordinances, policies, programs and studies that address storm water runoff quality. In addition to assessing these existing documents and programs, you should provide opportunities to the public to participate in the development of the program. Non-structural BMPs are preventative actions that involve management and source controls such as: policies and ordinances that provide requirements and standards to direct growth to identified areas, protect sensitive areas such as wetlands and riparian areas, maintain and/or increase open space (including a dedicated funding source for open space acquisition), provide buffers along sensitive water bodies, minimize impervious surfaces, and minimize disturbance of soils and vegetation; policies or ordinances that encourage infill development in higher density urban areas, and areas with existing infrastructure; education programs for developers and the public about project designs that minimize water quality impacts; and measures such as minimization of percent impervious area after development and minimization of directly connected impervious areas. Structural BMPs include: storage practices such as wet ponds and extended-detention outlet structures; filtration practices such as grassed swales, sand filters and filter strips; and infiltration practices such as infiltration basins and infiltration trenches. EPA recommends that you ensure the appropriate implementation of the structural BMPs by considering some or all of the following: pre-construction review of BMP designs; inspections during construction to verify BMPs are built as designed; post-construction inspection and maintenance of BMPs; and penalty provisions for the noncompliance with design, construction or operation and maintenance. Storm water technologies are constantly being improved, and EPA recommends that your requirements be responsive to these changes, developments or improvements in control technologies.

Table 1.6. Other Regulatory Drivers That Influence Post-Construction Stormwater

Regulatory Driver	Link With Post-Construction Program
Federal (many programs passed down to states for administration)	
NPDES Stormwater Permits for Construction *www.epa.gov/npdes/ stormwater/construction*	Applies to stormwater discharges from sites with disturbance of 1 acre or greater. Requires control of sediment and erosion and other wastes at the site. Operators must develop and implement a stormwater pollution prevention plan (SWPPP). Provides opportunity for local program to coordinate construction and post-construction phases in plan review, inspection, and maintenance.
NPDES Stormwater Permits for Industrial Activities *www.epa.gov/npdes/ stormwater/msgp*	Applies to stormwater discharges from certain categories of industrial activity. Requires site-specific SWPPP. Post-construction program should ensure that new industrial facilities are designed to prevent pollution and treat stormwater runoff from industrial areas.
Other NPDES Permits (e.g., wastewater discharge, etc.) *www.epa.gov/npdes*	Regulates discharges of process wastewater from municipal, commercial, and other wastewater treatment facilities.
Combined Sewer System – Long-Term Control Plan (NPDES) *www.epa.gov/npdes/cso*	Requires plan to address and minimize overflows from combined systems to waters of the U.S. Some communities have both an MS4 and a combined sewer system, and management practices should be coordinated. For instance, practices that limit the volume of stormwater discharges can also help reduce the incidence of CSOs. In addition, treatment practices such as street sweeping and catch basin cleaning can reduce floatables and sediment in CSOs.
Total Maximum Daily Load (TMDL) *www.epa.gov/owow/tmdl*	Addresses impaired waters through a program that develops total maximum daily loads (TMDLs). A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. Post-construction programs specify stormwater practices, retrofits, and/or site-based load limits for development and redevelopment that can address the pollutant(s) identified in the TMDL.
Source Water Assessment Program, Wellhead Protection Program, and Underground Injection Control Program *www.epa.gov/ogwdw*	Identifies and maps potential threats to water supply sources, and recommends protection plans. Stormwater facilities and retrofits can help protect water supply watersheds and wellhead areas. Certain practices may be limited, such as infiltration within wellhead protection areas. Hotspot land uses and discharges may be restricted.
Federal Wetland Permits (Section 404) *www.epa.gov/wetlands*	Regulates the discharge of dredged and fill material into waters of the United States, including wetlands. Stormwater practices that negatively impact streams and wetlands require permitting and are subject to denial. May push programs and site choices into low-impact development strategies to avoid impacts. Stormwater plans may have to be coordinated with mitigation plans required through the wetland permitting process.
Coastal Zone Management Program (CZMP) *http://coastalmanagement. noaa.gov*	Sets out planning goals and milestones for designated coastal zones. Stormwater controls should be coordinated with state-specific coastal zone management plans, which may include BMP performance standards. Nonstructural measures, such as wetland and marsh protection, can be incorporated into stormwater strategy to mesh with CZMP objectives.

Table 1.6. Other Regulatory Drivers That Influence Post-Construction Stormwater *(continued)*

Regulatory Driver	Link With Post-Construction Program
Homeland Security *www.dhs.gov* and *www.epa.gov/watersecurity*	Includes protection of drinking water supplies and wastewater systems as elements of the homeland security efforts of EPA and DHS. The Federal Emergency Management Agency (FEMA) is also a Homeland Security agency, and participation in the National Flood Insurance Program (NFIP) can be influenced by floodplain development policies and stormwater management.
National Flood Insurance Program *www.fema.gov/about/programs/nfip*	Allows local program to set standards for stormwater facilities located in floodplains (especially if fill is required) to ensure that flood conveyance is not impeded. Stormwater facilities may be factored into local floodplain modeling
State (variable by state)	
Dam Safety Program	Establishes regulatory overlay for impounding structures over a certain size or capacity, requiring regulatory coordination between local and state programs.
State Erosion and Sediment Control and Stormwater Programs	Provides performance and/or technology standards for construction stormwater plans and facilities. In most cases, requires coordination between construction and post-construction program elements, such as plan reviews and inspections.
State Water Supply Criteria	Where present, establishes standards for water supply planning and management that may include buffers and setbacks and/or stormwater treatment criteria. These should be coordinated with the local program.
State Scenic River, Open Space, Reforestation, and Resource Protection Programs	Where present, includes state-specific goals with link to stormwater management, such as setbacks from particular rivers.
State Well and Septic Permitting Programs	Provides standards for location of wells and septic fields that may impact on-lot practices, such as rain gardens and dry wells.
Regional	
Specific Regional Efforts; e.g., Chesapeake Bay, Great Lakes, Puget Sound	Where present, provides regional plans and programs that may have goals, objectives, and/or standards that influence a local stormwater program.
Local	
Existing Codes for Erosion Control, Stormwater, Zoning, Subdivision, Standing Water and Weeds (Nuisance), etc.	Establishes local rules for development density, streets, setbacks, etc. These codes may either support or impede stormwater program goals that aim to reduce impervious cover.
Greenway, Open Space, Recreation Plans, etc.	Provides planning framework that offers opportunity for coordination between stormwater and planning (e.g., riparian restoration in conjunction with greenway development, stormwater demonstration sites at public parks).

Table 1.7. Current Trends and Recommended Actions for Post-Construction Program

Current Trends	Recommended Actions
Post-Construction Program Development	
▶ Most Phase II MS4s operate program with $10K to $50K budget. ▶ General fund constitutes most of budget. ▶ Most programs have two or fewer staff working on post-construction stormwater.	Develop a post-construction program plan and budget to achieve a desired level of service. Seek a dedicated source of funding, such as a stormwater utility, for post-construction stormwater management. See **Chapter 2, Tools 1, 2.**
Linking Stormwater to Land Use Planning	
▶ For many programs, stormwater managers do not work closely with land use planners. ▶ Stormwater is considered after major land use decisions have been made.	Build stronger link between stormwater program and the comprehensive plan and land use decisions. Use watersheds to organize stormwater and land use. See **Chapter 3, Tool 4.**
Stormwater Management Approach & Criteria	
▶ Most local programs address flooding, and an increasing number also deal with water quality and channel protection. ▶ Fewer programs address groundwater recharge, reduction in overall runoff volume, or protection of sensitive receiving waters.	Develop a more holistic approach for post-construction stormwater management, including site design, source controls, stormwater practices, and protection of sensitive receiving waters. Distill a stormwater approach into criteria to be incorporated into ordinances and design guidance manuals. See **Chapter 4, Tool 3**.
Post-Construction Stormwater Ordinance	
▶ Approximately half of Phase II MS4s have adopted ordinance.	Adopt a post-construction stormwater ordinance in conjunction with or separate from ordinances for construction stormwater (erosion and sediment control) and illicit discharge detection and elimination. See **Chapter 5, Tool 3**.
Post-Construction Stormwater Guidance Manual	
▶ About 75% of states have some type of stormwater manual, but many manuals are out-of-date. ▶ Most state and local manuals ***do not*** provide incentives or credits for low-impact development and innovative practices.	Develop local design guidance, referencing the most appropriate state, regional, or local manual for BMP design standards. If not already provided, build in credits for low-impact development and innovative BMPs. See **Chapter 6, Tools 5, 8**.
Stormwater Plan Review Process	
▶ Most programs lack adequate staff to fully review stormwater plans. ▶ The average plan reviewer reviews 70 to 100 plans per year. ▶ Stormwater is considered late in the development review process.	Develop adequate in-house staffing or consider outsourcing the review function. Use pre-submittal meetings and concept plans to ensure that stormwater is considered early in the site planning process. See **Chapter 7, Tool 6**.

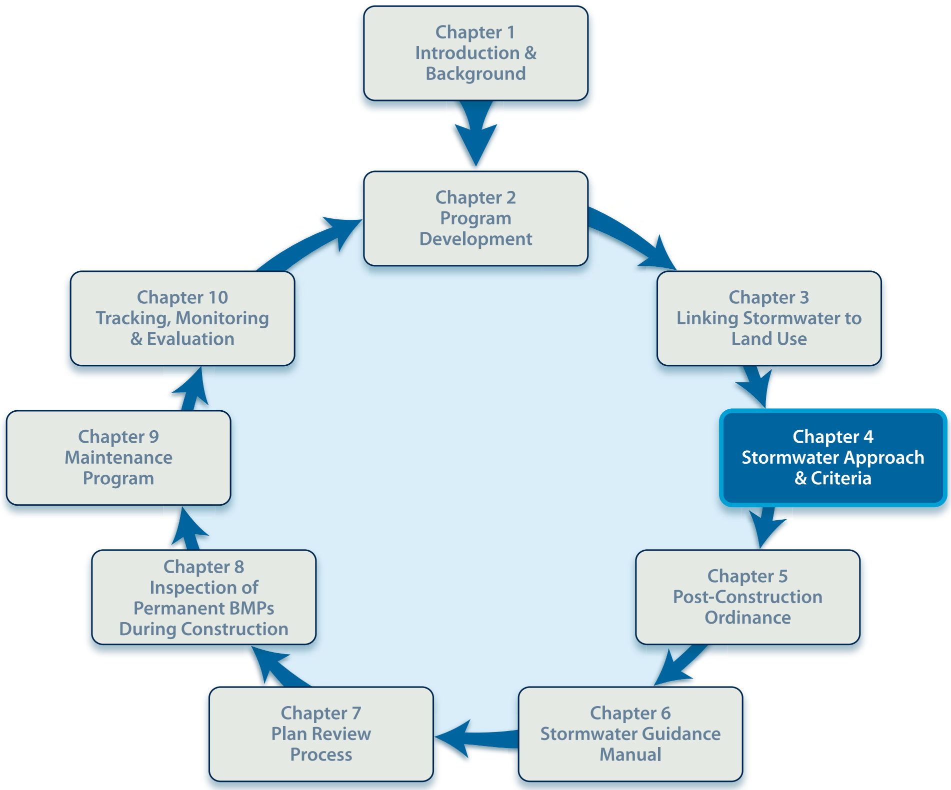
Table 1.7. Current Trends and Recommended Actions for Post-Construction Program *(continued)*

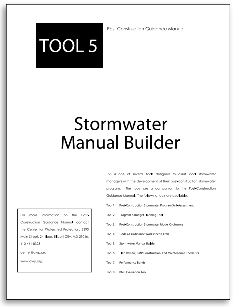
Current Trends	Recommended Actions
Inspection of Post-Construction BMPs During Installation	
► Most local programs conduct general construction inspections but might not focus on proper installation of post-construction BMPs. ► Many post-construction BMPs are not installed correctly.	Inspect post-construction BMPs at critical installation milestones. Develop standard forms and checklists for inspection staff. Establish adequate enforcement procedures. See **Chapter 8, Tools 6, 7**.
Post-Construction Maintenance	
► Most Phase II MS4s do not have an established maintenance program. ► Over half of programs do not use maintenance agreements. ► Lack of maintenance is the single most important cause of failure for BMPs and stormwater programs.	Clearly assign maintenance responsibility through policies, maintenance agreements, and easements. Develop a maintenance inspection and tracking program. Conduct outreach to responsible parties. See **Chapter 9, Tool 6**.
Program Tracking, Monitoring, and Evaluation	
► MS4s must establish measurable goals. ► Although annual reports are submitted, many programs do not evaluate their programs or develop useful indicators of success.	Develop a combination of outcome-based and output-based minimum measures to gauge program success and develop annual reports. Use evaluations to set program priorities, build public support, and demonstrate compliance. Maintain proper documentation to prepare for a potential regulatory audit. See **Chapter 10**.

Download Tools at: ***www.cwp.org/postconstruction***

Chapter 4

Developing a Stormwater Management Approach and Criteria





Companion Tools for Chapter 4
Download Post-Construction Tools at:
www.cwp.org/postconstruction

What's In This Chapter

- A recommended stormwater management approach
- Developing stormwater management criteria
  - Natural resources inventory
  - Runoff reduction
  - Water quality
  - Channel protection
  - Flood control
  - Redevelopment
- Developing a rainfall frequency spectrum
- Special stormwater criteria for sensitive receiving waters
- A watershed-based stormwater approach

4.1. Clarifying the Stormwater Management Approach

Chapter 2 described some fundamental steps to plan a post-construction stormwater program, and **Chapter 3** described a holistic approach for integrating stormwater with land use planning.

The next steps in program development are to put all the pieces in place to have an operational program. These include:

- Adopt or amend a stormwater ordinance.
- Develop, amend, or reference a stormwater guidance manual.
- Create a stormwater plan review process.
- Inspect permanent stormwater BMPs during initial installation and construction.
- Develop a maintenance program.
- Track, evaluate, and report on the program.

Before jumping into these tasks, it is important to clarify the overall stormwater management approach that the program will take. Stormwater management has seen many innovations in recent years. Each community should evaluate various approaches and figure out the best way to move the program forward and protect receiving waters.

This chapter outlines some basic techniques to:

- Select a stormwater management approach that will guide the program (**Section 4.2**)
- Develop stormwater management criteria to be used in ordinances and design guidance (**Sections 4.3** and **4.7**)
- Use rainfall data to link stormwater criteria to particular rainfall events (**Section 4.4**)
- Add criteria for special receiving waters (**Sections 4.5** and **4.7**)
- Consider incorporating a watershed-based approach for stormwater (**Section 4.6**)

Table 4.1 outlines some critical decisions that stormwater managers should explore to develop a local stormwater approach.

4.2. A Recommended Stormwater Management Approach

Most stormwater programs rely heavily on conventional end-of-pipe treatment of stormwater. Although these BMPs are a critical component of stormwater management, there is a broader range of options to consider. Many opportunities are missed by simply collecting and treating runoff ***after*** it has already been generated. In fact, there are many techniques to reduce stormwater impacts at the front end through site design and source control methods.

In this respect, there is a recommended hierarchy of stormwater treatment methods:

- **First, reduce runoff through design**: Use site planning and design techniques to reduce impervious cover, disturbed soils, and stormwater impacts. Use techniques such as conservation design, protecting critical open space and natural drainage features, and disconnecting a site's impervious cover to reduce the generation of stormwater runoff. At a broader community and watershed scale, this might also mean encouraging infill and development within targeted zones while preserving open spaces and functional landscapes beyond those areas (see **Table 4.2**).
- **Second, reduce pollutants carried by runoff**: Use source control and pollution prevention practices to reduce the exposure of pollutants to rainfall and runoff. Examples include keeping impervious surfaces clean, educating homeowners on proper yard waste and fertilization methods, handling and storing chemicals properly, and collecting and recycling hazardous chemicals (see **Table 4.3**).
- **Third, capture and treat runoff**: Design stormwater BMPs to collect and treat the stormwater that is generated after applying the site design and source control methods described above. Some stormwater collection and treatment can be in small-scale, distributed practices close to the source of runoff. Examples include rain gardens, filter strips, and pervious parking. Site designers should attempt to blend this approach with more conventional practices—such as ponds, stormwater wetlands, and filters—to come up with the most effective BMP design (see **Table 4.4**).

Table 4.1. Critical Decisions to Identify a Stormwater Management Approach

Land Use	What is the best way to integrate stormwater with land use? **Chapter 3** provides a detailed discussion on this important link.
Site Design	To what extent should the program promote and give credit for good site design practices, such as: ▶ Open space conservation ▶ Reduction of impervious surfaces and site disturbance ▶ Riparian, wetland, and waterway buffers ▶ Disconnection of impervious surfaces ▶ Site reforestation ▶ Desirable infill and redevelopment Although many stormwater programs would like to see these types of practices, fewer provide the programmatic and regulatory incentives to make it happen.
Source Controls and Pollution Prevention	While the conventional approach to stormwater management is to collect and treat runoff at some point downstream from the source, a more comprehensive approach is to reduce or eliminate the exposure of pollutants to runoff in the first place. Examples of source control and pollution prevention practices include: ▶ Street sweeping ▶ Pet waste education programs ▶ Household hazardous waste collection ▶ Spill containment and response A local program must decide how to incorporate these practices.
Conventional Stormwater BMPs	Some stormwater BMPs, such as ponds and basins, have been around for a long time. The local program must determine how to promote a better mixture of conventional and innovative practices (see below).
Low-Impact Development and Green Infrastructure BMPs	Many innovative practices can be distributed across the site and can do a good job of reducing runoff volumes and overall stormwater impacts. However, appropriate stormwater criteria and credits must be in place in order for developers and site designers to use the innovative practices. Also, the local program must have the administrative, plan review, inspection, and maintenance capabilities to ensure that conventional and innovative practices are properly designed, installed, and maintained
Special Receiving Waters	Not all watersheds are created equal. Some watersheds might require some customized approaches to stormwater management. Examples include: ▶ Nutrient control for lakes, water supply reservoirs, and wetlands ▶ Pollution prevention for groundwater supply areas ▶ Additional stormwater controls for impaired waters The community must identify special receiving waters and address these unique conditions in the stormwater criteria.
Site-by-Site or Watershed-Based	Most communities address stormwater on a site-by-site basis as development takes place. However, some programs have found that they can better address watershed impacts and promote more cost-effective BMPs with a watershed approach. Programs that want to pursue this approach should create the planning, regulatory, and financial tools to make it work.
Stormwater Management Criteria	All the decisions listed above in this table must be distilled into understandable and achievable criteria that are established in the stormwater ordinance and, ideally, discussed in detail in a stormwater guidance manual. Traditionally, most stormwater programs had criteria for flood control. However, today's programs are expected to also address water quality, downstream channel protection, and perhaps runoff reduction, groundwater recharge, and natural resources protection.

Table 4.2. **Hierarchy of Stormwater BMP Selection—Site Planning and Design**

1. Site Planning and Design

First, reduce runoff through design:

Plan the site to reduce stormwater runoff volume and impacts through design techniques.

- Preservation and/or Restoration of Undisturbed Natural Areas
- Preservation of Riparian Buffers, Floodplains, and Shorelines
- Preservation of Steep Slopes
- Preservation of Porous and Erodible Soils
- Preservation of Existing Topography
- Prairie/Meadow Restoration
- Site Reforestation
- Soil Amendments/Soil Rejuvenation
- Avoidance of Sensitive Areas
- Reduced Clearing and Grading Limits
- Conservation Development
- Reduced Roadway Lengths and Widths
- Shorter or Shared Driveways
- Shared Parking
- Reduced Building Footprints
- Reduced Parking Lot Footprints
- Reduced Setbacks and Frontages
- Use of Fewer or Alternative Cul-de-Sacs
- Use of Natural Drainageways
- Incentives for Infill and Redevelopment Within Targeted Development Zones

Photo courtesy of Pat Devlin

See **Tool 4: Codes and Ordinance Worksheet** for guidance on modifying local development codes to allow these practices.

Also see:
Better Site Design: A Handbook for Changing Development Rules in Your Community, Center for Watershed Protection, Inc.
www.cwp.org > Online Store > Better Site Design

Using Smart Growth Techniques as Stormwater Best Management Practices, U.S. EPA.
http://www.epa.gov/smartgrowth/stormwater.htm

Table 4.3. **Hierarchy of Stormwater BMP Selection—Source Control Practices**

2. Source Control and Pollution Prevention Practices

Second, reduce pollutants carried by runoff:
Reduce exposure of pollutants to rainfall and runoff through source control and pollution prevention practices.

Residential	Nonresidential
Natural Landscaping	Covered Loading Areas
Tree Planting	Covered Fueling Areas
Yard Waste Composting	Covered Vehicle Storage Areas
Septic System Maintenance	Storm Drain Disconnection
Driveway Sweeping	Downspout Disconnection
Street Sweeping	Street Sweeping
Household Hazardous Waste Collection Programs	Covered Dumpsters
Car Fluid Collection and Recycling Programs	Covered Materials Storage Areas
Downspout Disconnection	Secondary Containment Structures
Pet Waste Pickup	Spill Response Plans
Storm Drain Marking	Signage
	Employee Training

See Manual 8, *Pollution Source Control Practices, Urban Subwatershed Restoration Manual Series*, Center for Watershed Protection, Inc.
www.cwp.org > Online Store > Subwatershed Restoration Manuals

Table 4.4. Hierarchy of Stormwater BMP Selection—Stormwater Collection and Treatment

3. Stormwater Collection and Treatment

Third, capture and treat runoff:
Collect and treat stormwater runoff through small-scale distributed practices (close to the source of runoff) and other structural BMPs.

Small-Scale Distributed Practices	Other Structural BMPs
Downspout Disconnection	Infiltration Devices
Impervious Cover Disconnection	Larger Bioretention Areas
Rainwater Harvesting	Extended Detention Ponds
Rain Gardens	Wet Ponds
Small Bioretention Areas	Constructed Stormwater Wetlands
Dry Wells	Engineered Swales
French Drains	Filtering Practices
Green Rooftops	Manufactured BMPs
Porous and Pervious Pavement	
Stormwater Planters	
Vegetated Filter Strips	
Vegetated Channels/Swales	

Photo courtesy of Tim Schueler

See **Tool 5: Manual Builder** for guidance on good design references.

The local program should strive to provide standards and guidelines for all three categories of stormwater treatment. **Tables 4.2** through **4.4** provide candidate BMPs and resources for each category. **Tool 5: Manual Builder** provides links to design manuals across the country that provide good examples.

4.3. Developing Stormwater Management Criteria

Stormwater management criteria are the technical core of a stormwater ordinance (**Chapter 5**) and a major focus of stormwater guidance manuals (**Chapter 6**). They establish the design objectives for BMPs, and they will influence directly the types and sizes of these practices.

The list below describes the technical stormwater criteria that are adopted by stormwater programs around the country within ordinances and design guidance. **Tool 3: Model Stormwater Ordinance** contains model language for each of these criteria. It is important to note that the Phase I and II MS4 permit program is concerned largely with criteria that help meet water quality standards (1 through 4 below). Flood control (5) is historically a more common and locally applied criterion.

1 – Natural Resources Inventory (NRI)*:* identify the site's critical natural features and drainage patterns early in the site planning process.

2 – Recharge and/or Runoff Reduction (RR): maintain groundwater recharge rates and/or reduce post-development runoff volume by a set amount.

3 – Water Quality Volume (WQV): capture and treat runoff from the water quality storm to remove certain target pollutants.

4 – Channel Protection (CP)*:* design the stormwater system so that conveyances and outfalls are stable and will not erode downstream channels or cause damage to downstream habitats.

5 – Flood Control (FC): control peak rates to reduce downstream flooding. The criterion can have two components:

Overbank (Minor Storm) Flood Control: provide storage for storm events that might cause routine flooding to downstream property, conveyance systems, and drainage infrastructure.

Extreme (Major Storm) Flood Control: provide storage for infrequent but large storm events that might cause downstream flooding and damage and/or enlarge the boundaries of the floodplain.

6 – Redevelopment*:* provide flexibility for redevelopment sites where stormwater compliance might be more difficult and can be met through a variety of strategies. A redevelopment criterion provides flexibility in meeting criteria 1 through 5 above where a site meets the definition of redevelopment.

A unified approach is the most effective way to develop stormwater management criteria and present them within the local ordinance and/or guidance manual. The goal of a unified framework is to develop a consistent approach for designing BMPs that can:

Perform effectively: Manage the range of stormwater flows and volumes that will actually mitigate local stormwater problems; protect public health and safety; and reduce flood, water quality, and channel erosion hazards.

Perform efficiently: Manage just enough runoff volume to address the problems but not over-control them. Providing more stormwater storage is not always better, and it can greatly increase construction costs and consume valuable land.

Be simple to administer: Be understandable, relatively easy to calculate with current hydrologic models, and workable over a range of development conditions and intensities. In addition, stormwater management criteria should be clear and straightforward, and backed up by the local stormwater ordinance, to avoid needless disputes between design engineers and plan reviewers when they are applied to development sites.

Promote multipurpose, integrated stormwater design: Allow for flexible and creative design to integrate into community aesthetics, enhance property values, and serve multiple purposes (such as stormwater and recreation).

Be flexible to respond to special site conditions: Define certain site conditions or development scenarios where individual stormwater sizing criteria may be relaxed or waived when they are clearly inappropriate or infeasible.

Figure 4.1 graphically portrays a unified, or nested, approach for the six stormwater management criteria listed above.

The "nesting" of the criteria portrayed in **Figure 4.1** can best be understood by considering the overall volume of runoff generated by a site. Each of the stormwater management criteria relates to a certain volume of the overall runoff volume to be managed. For instance, runoff reduction and water quality management usually entail capturing a smaller volume of water than channel protection and flood control. However, the volume of runoff that is infiltrated, captured, and/or treated in a water quality BMP can reduce the overall volume that remains to be treated for downstream channel protection and flood control. Put another way, a site that maximizes runoff reduction through infiltration, soil absorption, and capture and reuse can reduce the size and possibly the need for larger, structural storage devices like pond and basins.

The criteria outlined in this section should be considered as candidate (or potential) criteria for a local program. The criteria should be adapted to local conditions (soils, geology, water table, etc.), the level of program sophistication, and local goals and concerns. **Table 4.5** provides some guidance for adapting the criteria to unique conditions, such as good (or poor)

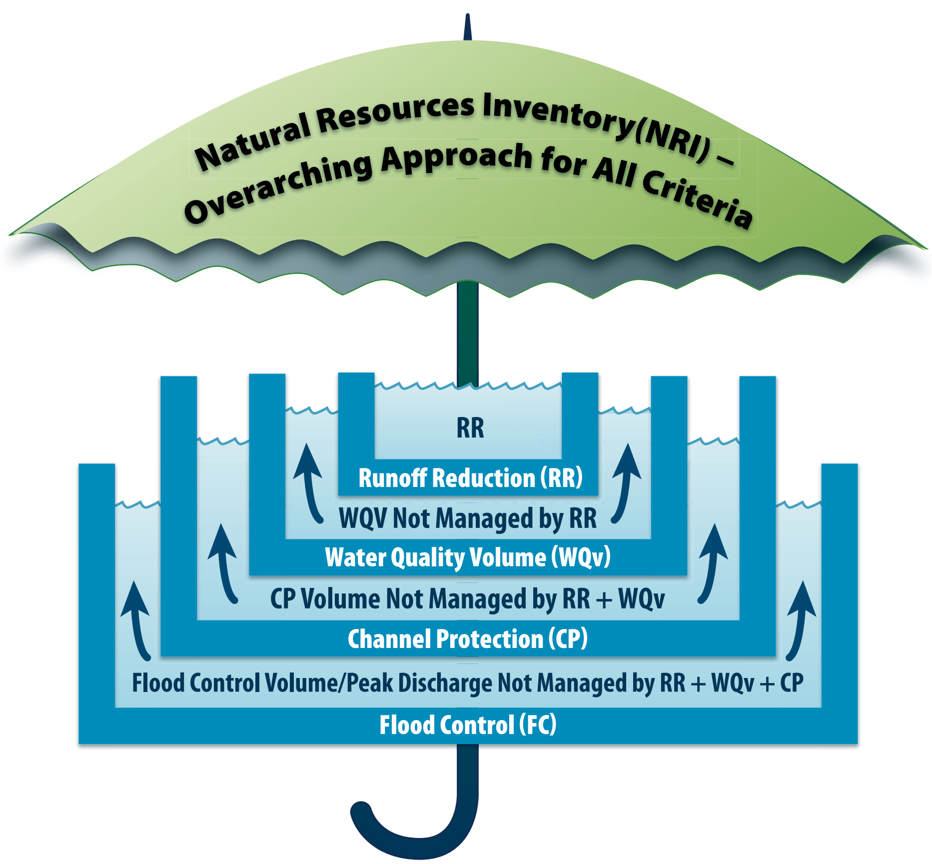


Figure 4.1. Graphic representation of the nested approach to stormwater management criteria

Table 4.5. Suggested Adaptations for Stormwater Management Criteria in Different Settings

Variable Settings for Stormwater Management	Possible/Conceptual Adaptations to Stormwater Criteria
Generally good soils for infiltration; few constraints, such as shallow bedrock	► Apply criterion 1 (natural resources) as a planning and site design tool. ► Collapse criteria 2 through 4 (runoff reduction, water quality, and channel protection) into a single criterion for ***Runoff Reduction***. ► Define the Runoff Reduction Volume as the 1-year, 24-hour rainfall depth, or a similar criterion adopted by the local program. ► Each site should maximize runoff reduction through infiltration, canopy interception, evaporation, transpiration, and/or rainwater harvesting. ► Any fraction of the Runoff Reduction Volume that cannot feasibly be eliminated from site runoff should be treated through extended detention[a] or extended filtration.[b] ► Allow Runoff Reduction waivers for sites where it is not feasible. Require that the full Runoff Reduction Volume be treated in an applicable water quality BMP. ► Apply criterion 5 (flood control) where it is needed to protect downstream property, conveyance systems, and infrastructure. If applicable, allow a reduction in the required volume for all or part of volume reduced through Runoff Reduction BMPs.
Arid climates	► Generally follow the guidance above for areas with good infiltration potential; rely on a balanced approach of infiltration and evaporation. Provide waivers where infiltration is not feasible or advisable. ► Select BMPs based on criteria including ability to reduce sediment loads. ► Apply criterion 5 (flood control), ensuring that large, damaging storm events have safe conveyance to an adequate downstream system.
Generally poor soils for infiltration; possible other constraints such as high water table or shallow bedrock	► Apply criterion 1 (natural resources) as a planning and site design tool. ► Apply criterion 2 (runoff reduction) to establish a minimum, or modest, level of performance for runoff reduction, such as reducing the first 0.5 inch of runoff from the post-development condition (or an appropriate local standard). In some locations, infiltration might not be a feasible runoff reduction method. ► Allow waivers for sites where runoff reduction can be proven to be infeasible (the volume should still be required to be treated for water quality; see below). ► Apply criterion 3 (water quality) to a prescribed "water quality volume." This should be the 90th percentile rainfall event (see **Table 4.9**) or an applicable local standard. ► Apply criteria 4 and 5 (channel protection, flood control) where they are needed to protect downstream channels, property, conveyance systems, and infrastructure. If applicable, allow a reduction in the required volume for all or part of volume reduced through runoff reduction and water quality BMPs.

Table 4.5. Suggested Adaptations for Stormwater Management Criteria in Different Settings *(continued)*

Variable Settings for Stormwater Management	Possible/Conceptual to Adapt Stormwater Criteria
Karst	► Combine criteria 1 (natural resources) and 2 (runoff reduction) as a planning and site design tool. Include identification of sinkholes and karst features in early site layout, with possible setbacks from these features. Promote infiltration across broad landscape areas (such as open space, swales, and soil amendment) instead of concentrating site runoff to small, engineered infiltration BMPs. Provide credits for sites that do a good job with site design. ► Apply criterion 3 (water quality) to a prescribed "water quality volume." This should be the 90^{th} percentile rainfall event (see **Table 4.9**) or an applicable local standard. Require pretreatment and/or lining for BMPs sited on karst with shallow soil cover. ► Apply criteria 4 (channel protection). Develop special provisions for discharges to sinkholes and areas with no downstream surface channel to handle increased site runoff. ► Apply criterion 5 (flood control) where it is needed to protect downstream property, conveyance systems, and infrastructure. If applicable, allow a reduction in the required volume for all or part of volume reduce through site design, water quality, and channel protection BMPs.
Watersheds with an extensive existing ditch system (past agricultural practices)	► Adapt criterion 1 (natural resources) to include ditch restoration and/or naturalization as a possible post-construction BMP. Practices can include adding sinuosity, restoring prior-converted wetlands, and streambank and riparian planting. ► See other cases in this table for options for criteria 2 and 3. ► Criteria 4 and 5 (channel protection, flood control) should consider ditch capacity. As with criterion 1, ditch restoration can play a role in meeting channel protection, and possibly flood control, objectives.
Redevelopment	► Allow flexible compliance strategies for all criteria based on specific program goals and site conditions.

[a] Extended detention includes stormwater BMPs that capture runoff and release it slowly over an *extended* period, usually 12 to 24 hours. The goal is to maintain a flow rate and velocity that do not damage downstream channels.

[b] Extended filtration includes stormwater BMPs that capture runoff and delay its release until after most of the site runoff for a given storm has passed to the downstream system. Examples are bioretention and water quality swales with underdrains that delay delivery of stormwater from small sites to the downstream system by six hours or more.

soils for infiltration, karst, arid climates, and locations with extensive ditch systems. The categories in the table are fluid in that more than one category may apply to a given community, and not every possible scenario is identified. Also, the adaptations in the table are for illustrative purposes; a stormwater manager must choose the most appropriate criteria and adaptations for the local program.

Tables 4.7 through **4.12** at the end of this chapter provide more detail for each of the six stormwater management criteria. These tables are most useful for assembling language and standards for stormwater ordinances and guidance manuals (again, local adaptations are strongly encouraged). The tables provide potential standards and candidate BMPs that can be used to meet each of the criteria. Finally, the tables provide links to programs, design manuals, or existing resources that provide examples of the criteria. (**Tool 5: Manual Builder Tool** contains additional examples.)

4.4. Developing a Rainfall Frequency Spectrum

Rainfall Frequency Spectrum (RFS) curves (which are also known as "rainfall distribution plots") are useful tools to assist stormwater managers with the development of stormwater management criteria, particularly the criteria that relate to smaller storm events (runoff reduction or recharge, water quality).

The RFS helps to link the various criteria with particular rainfall events. For instance, if the local water quality criteria relate to treatment of runoff from the 90th percentile storm event, an RFS curve will help establish this particular rainfall depth. **Figure 4.2** provides guidance on creating RFS curves, and **Table 4.6** provides rainfall depth frequency statistics for cities across the United States.

4.5. Special Stormwater Criteria for Sensitive Receiving Waters

One of the unique development situations for which basic stormwater management criteria may be modified is when sensitive receiving waters must be protected. This recognizes the fact that not all stormwater discharges are created equal, and that certain watersheds require a customized approach.

There has been a trend in recent years to develop special stormwater criteria to protect sensitive water resources **(CWP, 2006)**. Special stormwater design criteria have been created by state and local stormwater management programs to protect each of the following:

- Lakes and water supply reservoirs
- Cold water fisheries (trout and salmon streams)
- Groundwater
- Wetlands
- Impaired waters

Special stormwater design criteria typically make use of one or more of the following strategies:

- Enhancing stormwater BMP design features to provide a higher level of pollutant removal (e.g., sizing, internal geometry, vegetation, pretreatment, multiple treatment methods, etc.).
- Adding runoff reduction, groundwater recharge, and/or downstream analysis to provide greater protection from streambank erosion.
- Requiring the use of certain stormwater BMPs to provide additional protection for sensitive receiving waters (e.g., requiring specific stormwater BMPs at known stormwater hotspots to reduce pollutant loads).
- Instituting special design criteria for individual stormwater BMPs to enhance performance or diminish downstream impacts (e.g., for cold water fisheries, to mitigate stream warming caused by stormwater ponds).
- Establishing restrictions on where stormwater BMPs may be located at a site and where they may discharge.

Additional information on each of the special stormwater design criteria is presented in **Tables 4.13** through **4.17** at the end of this chapter.

4.6. A Watershed-Based Stormwater Approach

An emerging trend for stormwater programs is to move beyond the site-by-site design and installation of BMPs. Some programs enhance the site-by-site approach with a master stormwater plan or watershed-based plan. Such a plan integrates what is required at the site level with broader watershed projects to achieve certain watershed objectives.

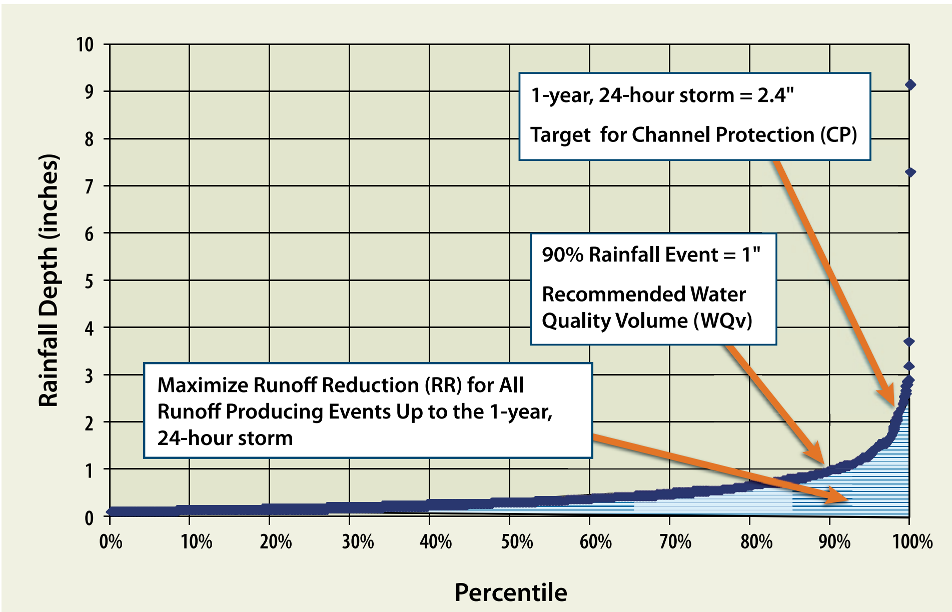
For instance, the plan might specify stream and riparian restoration projects, stormwater retrofits, impervious disconnection programs, wetland preservation, subregional BMPs, and/or watershed outreach activities. A site that is being developed within the subject watershed might contribute funds, land, or design support to a watershed project in lieu of (or, in some cases, as a supplement to) the installation of on-site BMPs. **Figure 4.3** shows several examples of watershed-based stormwater projects.

The stormwater ordinance must establish the authority to allow contributions to regional or

A Rainfall Frequency Spectrum (RFS) is a tool that stormwater managers should use to analyze and develop local stormwater management criteria and to provide the technical foundation for the criteria.

Over the course of a year, many precipitation events occur within a community. Most events are quite small, but a few can create several inches of rainfall. An RFS illustrates this variation by describing how often, on average, various precipitation events (adjusted for snowfall) occur during a normal year.

The graph below provides an example of a typical rainfall frequency spectrum and shows the percentage of rainfall events that are equal to or less than an indicated rainfall depth. As shown, the majority of storm events are relatively small, but there is a sharp upward inflection point that occurs at about 1 inch of rainfall (90% rainfall event). The 90% rainfall depth is the recommended standard for the Water Quality Volume (see **Table 4.7**).



Rainfall Frequency Spectrum for Minneapolis-St. Paul, MN (1971–2000) with several noteworthy rainfall events identified (adapted from MSSC, 2005).

Guidance on creating an RFS is provided below. If a community is large in area or has considerable variation in elevation or aspect, the RFS analysis should be conducted at multiple stations.

1. Obtain a long-term rainfall record from an adjacent weather station (daily precipitation is fine, but try to obtain at least 30 years of daily record). NOAA has several Web sites with long-term rainfall records (see ***http://www.nesdis.noaa.gov***). Local airports, universities, water treatment plants, or other facilities might also maintain rainfall records.
2. Edit out small rainfall events than are 0.1 inch or less, as well as snowfall events that do not immediately melt.
3. Using a spreadsheet or simple statistical package, analyze the rainfall time series and develop a frequency distribution that can be used to determine the percentage of rainfall events less than or equal to a given numerical value (e.g., 0.2, 0.5, 1.0, 1.5 inches).
4. Construct a curve showing rainfall depth versus frequency, and create a table showing rainfall depth values for 50%, 75% 90%, 95% and 99% frequencies.
5. Use the data to define the Water Quality storm event (90th percentile annual storm rainfall depth). This is the rainfall depth that should be treated through a combination of Runoff Reduction (**Table 4.6**) and Water Quality Volume treatment (**Table 4.7**).
6. The data can also be used develop criteria for Channel Protection (**Table 4.8**). The 1-year storm (approximated in some areas by the 99% rainfall depth) is a good standard for analyzing downstream channel stability.
7. Other regional and national rainfall analysis such as TP-40 (NOAA) or USGS should be used for rainfall depths or intensity greater than 1 year in return frequency (e.g., 2-, 5-, 10-, 25-, 50-, or 100-year design storm recurrence intervals).

Figure 4.2. Creating a Rainfall Frequency Spectrum (RFS) to assist with development of stormwater management criteria

Table 4.6. Rainfall Statistics and Frequency Spectrum Data for Select U.S. Cities

City	Precipitation		Rainfall event: Depth in inches[a]				
	Annual Inches	Days[b]	50%	75%	90%[c]	95%	99%[d]
Atlanta, GA	50	77	0.5	0.9	1.6	2.1	3.4
Knoxville, TN	48	85	0.4	0.7	1.2	1.5	2.4
New York City, NY	44	74	0.4	0.7	1.2	1.7	2.7
Greensboro, NC	43	73	--	--	1.6	--	2.7
Boston, MA	43	76	0.4	0.6	1.2	1.6	2.6
Baltimore, MD	42	71	0.4	0.8	1.2	1.6	2.5
Buffalo, NY	41	88	0.3	0.5	0.8	1.1	1.8
Washington, DC	39	67	0.4	0.8	1.2	1.7	2.4
Columbus, OH	39	79	0.3	0.6	1.0	1.3	2.1
Kansas City, MO	38	63	0.4	0.7	1.1	1.7	3.2
Seattle, WA	37	90	--	--	1.3	1.6	1.7
Burlington, VT	36	79	0.3	0.5	0.8	1.1	1.7
Dallas, TX	35	32	--	--	1.1	--	3.2
Austin, TX	34	49	--	--	1.4	--	3.2
Minneapolis, MN	29	58	0.3	0.6	1.0	1.4	2.4
Coeur D'Alene, ID	26	88	0.2	0.3	0.5	0.7	1.1
Salt Lake City, UT	17	44	0.2	0.4	0.6	0.8	1.2
Denver, CO	16	37	--	--	0.7	--	--
Los Angeles, CA	13	22	--	--	1.3	--	--
Boise, ID	12	38	--	--	0.5	--	--
Phoenix, AZ	8	29	--	--	0.8	--	1.1
Las Vegas, NV	4	10	--	--	0.7	--	0.8

Notes: Dashed lines indicate no data available to compute.

[a] Excludes rainfall depths of 0.1 inch or less.

[b] Average days per year with measurable precipitation.

[c] The 90% storm is frequently used to define the water quality volume.

[d] The 99% storm is an approximation of the 1-year storm in some areas (but is not an exact replication because the statistical analysis is different). The 1-year, 24-hour storm is frequently used as a design storm for downstream channel protection. The recommended approach is to conduct an analysis of the runoff generated by the 1-year, 24-hour storm to derive channel protection criteria.

Urban Stormwater Retrofits

Stream and Riparian Restoration

Rooftop Disconnection Programs

Innovative BMPs at Municipal Facilities

Photo courtesy of Albemarle County, VA

Enhancements to Regional BMPs

Watershed Outreach Activities

Figure 4.3. Several examples of projects that can be included in a watershed-based stormwater management program that goes beyond site-by-site compliance

watershed projects, and any general conditions for their application. Technical elements can be in the stormwater guidance manual.

A local stormwater program can incorporate a regional or watershed approach through the following means:

- ***Pro rata share***. The stormwater ordinance specifies that projects within the drainage area (or "service" area) of a regional or watershed project pay a pro rata share contribution in lieu of complying with on-site requirements (at least in part). Generally, such contributions may be used only to reimburse construction costs. The mechanics of such a program (calculation of the "share" based on discharge, pollutant loads, or impervious cover) should be included in the guidance manual.
- ***Fee in lieu***. The ordinance may specify that projects that meet certain criteria may (or must) pay a fee that contributes to a watershed project in lieu of some on-site requirements. The fee procedure and calculations should be included in the guidance manual, with provision for the fee to reflect realistic project costs that will probably increase over time. As opposed to the pro rata share approach, the fee may be able to be used for a wider range of project costs, including design, construction, and maintenance.
- ***Capital improvement program/local implementation***. Even if new development and redevelopment projects do not contribute funds or other services to the implementation of watershed projects, the local program may still wish to adopt a watershed approach that can be implemented in parallel with required BMPs at development sites. In urbanized and urbanizing watersheds, stormwater retrofitting or stream restoration might be important strategies to address impacts from existing development. Individual projects should be identified in a watershed plan or stormwater master plan, with implementation strategies tied to the capital improvement program, grants, cost-share programs, and other funding sources.

4.7. Detailed Stormwater Management Criteria Tables

The following tables provide more detailed guidance on specific language and standards that can be adapted for stormwater management criteria. **Tables 4.7** through **4.12** address the six criteria introduced in **Section 4.3**. **Tables 4.13** through **4.17** specify additional criteria for special receiving waters. The tables provide potential standards; however, it is important for local stormwater managers to assess and adapt the most appropriate standards.

The detailed tables address the following criteria:

Basic Criteria

Table 4.7 – Natural Resources Inventory (NRI)

Table 4.8 – Runoff Reduction (RR)

Table 4.9 – Water Quality Volume (WQv)

Table 4.10 – Channel Protection (CP)

Table 4.11 – Flood Control (FC)

Table 4.12 – Redevelopment

Special Receiving Waters

Table 4.13 – Lakes and Water Supply Reservoirs

Table 4.14 – Trout and Salmon Streams

Table 4.15 – Groundwater

Table 4.16 – Wetlands

Table 4.17 – Impaired (TMDL-Listed) Waters

Table 4.7. Stormwater Criteria for Ordinances and Design Guidance: Natural Resources Inventory

Criterion 1: Natural Resources Inventory (NRI) – Conduct inventory of site natural features.	
Explanation	As a first step in site planning, identify natural resources elements that should be protected in order to reduce stormwater impacts *by design*. These elements include natural drainage features, riparian buffers, wetlands, steep slopes, soils with high infiltration capacity, significant forest, prairie patches, trees, and natural communities. A local or state program can provide stormwater credits for conserving these features and/or using site design techniques to mitigate impacts on natural resource features. The effect of the credit is to reduce the required stormwater volume or treatment requirements for Runoff Reduction, Water Quality Volume, Channel Protection, and Flood Control (see Criteria 2 through 5, **Tables 4.8** through **4.11**).
Potential Standards	Identify NRI features on a concept stormwater plan. Provide credits for designs that protect or restore NRI features.
Candidate BMPs to Meet Standards	► Open space conservation, preservation, reforestation ► Conservation of soils with high infiltration capacity ► Riparian, wetland and waterway buffers ► Conservation easements ► Open space or conservation design ► Green Infrastructure and Smart Growth planning at community and regional scales
Examples from Existing Programs – See Tool 5: Manual Builder for more examples and links	*Pennsylvania Stormwater Best Management Practices Manual*, Ch. 4, Integrating Site Design and Stormwater Management ***http://www.depweb.state.pa.us/watershedmgmt/cwp/view.asp?a=1437&q=529063&watershedmgmtNav=|*** *New Jersey Stormwater Best Management Practices Manual*, Ch. 2, Low-Impact Development Techniques ***http://www.njstormwater.org/bmp_manual2.htm*** *Minnesota Stormwater Manual*, Ch. 11, Applying Stormwater Credits to Development Sites ***http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html*** *Georgia Green Growth Guidelines*, Section 1, Site Fingerprinting Utilizing GIS and GPS ***http://crd.dnr.state.ga.us/content/displaycontent.asp?txtDocument=969*** *Urban Watershed Forestry Manual Series*, Parts 2 and 3, Center for Watershed Protection and USDA Forest Service ***www.cwp.org*** > Resources > Special Resource Management > Urban Forestry *Forest Conservation Technical Manual: Guidance for the Conservation of Maryland's Forests During Land Use Changes Under the 1991 Forest Conservation Ac*t, Metropolitan Washington Council of Governments (Not available online.)

Table 4.8. Stormwater Criteria for Ordinances and Design Guidance: Runoff Reduction

Criterion 2: Runoff Reduction (RR) – Reduce volume of post-development runoff.	
Explanation	Some amount of the post-development runoff should be permanently reduced through disconnecting impervious areas, maintaining sheetflow to areas of natural vegetation, infiltration practices, and/or collection and reuse of runoff. More stringent criteria should apply to sensitive receiving waters. Groundwater recharge/infiltration requirements should not apply to stormwater hotspots and contaminated soils and should be adjusted as appropriate for sites in close proximity to karst, drinking water supply wells, building foundations, fill slopes, etc. Areas characterized by high water table, shallow bedrock, clay soils, contaminated soils, and other constraints should evaluate how much runoff can practically be reduced and modify the recommended standards accordingly.
Potential Standards	**Option 1: Groundwater Recharge/Infiltration** Replicate the pre-development recharge volume, based on regional average recharge rates for hydrologic soil groups. ▶ **Residential Sites**: Post-development recharge = 90% of pre-development recharge ▶ **Nonresidential Sites**: Post-development recharge = 60% of pre-development recharge **Option 2: Overall Runoff Reduction** ▶ No increase in the overall runoff volume compared to the pre-development condition for all storms less than or equal to the 2-year, 24-hour storm, OR ▶ Capture and remove from the site hydrograph the volume of water associated with the 80th percentile storm event (or a locally appropriate and achievable standard—this might be the 90th percentile storm event for areas with good infiltration potential).
Candidate BMPs to Meet Standards	▶ Site design that reduces and disconnects impervious cover ▶ Soil amendments, soil rejuvenation ▶ Rainwater collection and reuse ▶ Pervious parking ▶ Bioretention ▶ Rain gardens, on-lot infiltration practices ▶ Infiltration swales, trenches, and basins ▶ Enhanced filter strips (with soil amendments and vegetation) ▶ Green roofs
Examples from Existing Programs – See Tool 5: Manual Builder for more examples and links	*Wisconsin Post-Construction Stormwater Management* ***http://dnr.wi.gov/runoff/stormwater/post-constr*** *Pennsylvania Stormwater Best Management Practices Manual*, Ch. 3, Stormwater Management Principles and Control Guidelines ***http://www.depweb.state.pa.us/watershedmgmt/cwp/view.asp?a=1437&q=529063&watershedmgmtNav=|*** *Etowah Habitat Conservation Plan—Stormwater Management Policies* ***http://www.etowahhcp.org/policies.htm*** *Best Management Practices for Stormwater Quality*, American Public Works Association, Kansas City Metro Chapter ***http://www.kcapwa.net/kcmetro/Specifications.asp*** *Better Site Design: A Handbook for Changing Development Rules in Your Community*, Center for Watershed Protection, Inc. ***www.cwp.org*** > Online Store > Better Site Design

Table 4.9. Stormwater Criteria for Ordinances and Design Guidance: Water Quality Volume

Criterion 3: Water Quality Volume (WQv) – Capture and treat large percentage of annual pollutant load.	
Explanation	Post-development runoff that is not permanently removed through the application of the RR criterion (Criterion 2, **Table 4.8**) should be captured and treated in a water quality BMP. This standard applies to the *Water Quality Volume* (WQv), or the volume of runoff that contains most of the annual pollutant load. More stringent criteria should apply to sensitive receiving waters. States, regions, or localities should evaluate the pollutants of concern that should drive BMP selection and design. Nationally, the most common pollutants of concern include sediment, particulate, soluble nutrients (phosphorus and nitrogen), and bacteria. BMPs or combinations of BMPs that achieve the highest pollutant load reduction for the pollutants of concern should be selected.
Potential Standards	WQv = runoff volume generated by the 90th percentile storm event, based on regional rainfall frequencies (see **Section 4.4**). All runoff removed through the RR criterion (see Criterion #2 in **Table 4.8**) counts toward treating the WQv. The remainder must be treated in an acceptable water quality BMP.
Candidate BMPs to Meet Standards	► Filtering practices—bioretention, sand filters, manufactured filters ► Water quality swales, dry swales ► Linear stormwater wetlands ► Stormwater ponds ► Vegetated filter strips ► Green roof
Examples from Existing Programs – See Tool 5: Manual Builder for more examples and links	*Maryland Stormwater Design Manual* ***http://www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater*** *Maine Stormwater Best Management Practices Manual, Volume II, Phosphorus Control in Lake Watersheds: A Technical Guide to Evaluating New Development* ***http://www.maine.gov/dep/blwq/docstand/stormwater/stormwaterbmps*** *California Stormwater Best Management Practice Handbooks: New Development and Redevelopment*, California Stormwater Quality Association ***http://www.cabmphandbooks.com***

Table 4.10. Stormwater Criteria for Ordinances and Design Guidance: Channel Protection

Criterion 4: Channel Protection (CP) – Convey stormwater to protect downstream channels	
Explanation	The stormwater system should be designed so that increased post-development discharges that are ***not*** mitigated through application of Criteria 1 through 3 will not erode natural channels or steep slopes. This will protect in-stream habitats and reduce in-channel erosion. Conveyance systems can be designed to reduce stormwater volume, create non-erosive velocities, incorporate native vegetation, and, in some cases, restore existing channels that are degraded. This design process involves careful analysis of the downstream system, beginning with the site's position within a watershed or drainage area. First, compare the size of the on-site drainage area *at each of the site's discharge points* to the total drainage area of the receiving channel or waterway. Note that the point of analysis might not always be the property boundary of the site, but the point where the site's discharge joins a natural drainage swale, channel, stream, or waterbody. The recommended standard below presents a tiered system for CP compliance based on the site/drainage area analysis discussed above.
Potential Standards	At each discharge point from the site, if the on-site drainage area is ***less*** than 10% of the total contributing drainage area to the receiving channel or waterbody, the following Tier 1 performance standards must apply: **Tier 1 Performance Standards** ► Wherever practical, maintain sheetflow to riparian buffers or vegetated filter strips. Vegetation in buffers or filter strips must be preserved or restored where existing conditions do not include dense vegetation (or adequately sized rock in arid climates). ► Energy dissipaters and level spreaders must be used to spread flow at outfalls. ► On-site conveyances must be designed to reduce velocity through a combination of sizing, vegetation, check dams, and filtering media (e.g., sand) in the channel bottom and sides. ► If flows cannot be converted to sheetflow, they must be discharged at an elevation that will not cause erosion or require discharge across any constructed slope or natural steep slopes. ► Outfall velocities must be non-erosive from the point of discharge to the receiving channel or waterbody where the discharge point is calculated. At each discharge point from the site, if the on-site drainage area is ***greater*** than 10% of the total contributing drainage area to the receiving channel or waterbody, then the Tier 1 performance standards must apply ***plus*** the following Tier 2 performance standards: **Tier 2 Performance Standards** ► Sites greater than 10 acres (or a site size deemed appropriate by the local program) must perform a detailed downstream (hydrologic and hydraulic) analysis based on post-development discharges. The downstream analysis must extend to the point where post-development discharges have no significant impact (and do not create erosive conditions) on receiving channels, waterbodies, or storm sewer systems. ► If the downstream analysis confirms that post-development discharges will have an impact on receiving channels, waterbodies, or storm sewer systems, then the site must incorporate some or all of the following to mitigate downstream impacts: (1) Site design techniques that decrease runoff volumes and peak flows. (2) Downstream stream restoration or channel stabilization techniques, as permitted through local, state, and federal agencies. (3) 24-hour detention of the volume from post-development 1-year, 24-hour storm (the volume is stored and gradually released over a 24-hour period). Runoff volumes controlled through the application of RR and WQv measures (Criteria 2 and 3, **Tables 4.8** and **4.9**) may be given credit

Table 4.10. Stormwater Criteria for Ordinances and Design Guidance: Channel Protection *(continued)*

Variable Settings for Stormwater Management	Possible/Conceptual to Adapt Stormwater Criteria
Potential Standards (continued)	(toward meeting storage requirements. Discharges to cold water fisheries should be limited to 12-hour detention. ► Sites less than 10 acres (or a site size deemed appropriate by the local program) must use a combination of the mitigation techniques listed above and verify that stormwater measures provide 12- to 24-hour detention of the volume from post-development 1-year, 24-hour storm (again, allowing credits through the application of RR and WQv measures). A detailed downstream analysis is not required unless the local program identifies existing downstream conditions that warrant such an analysis.
Candidate BMPs to Meet Standards	► Water quality swales ► Grass swales ► Level spreaders and energy dissipaters ► Riparian and floodplain restoration ► Bioretention with extra volume of soil media and/or underdrain stone ► Pervious parking with underground storage ► Outfall designs that use natural channel and velocity reduction features ► Ponds and pond/wetland systems that provide peak flow control
Examples from Existing Programs – See Tool 5: Manual Builder for more examples and links	*Stormwater Management Manual for Western Washington*, Volumes I and V ***http://www.ecy.wa.gov/programs/wq/stormwater/manual.html*** *Bioretention Design Spreadsheet*, North Carolina State University, Stormwater Engineering Group ***http://www.bae.ncsu.edu/stormwater/downloads.htm*** (system to assign detention credit to bioretention) *Integrated Stormwater Management Design (iSWMD™) for Site Development*, Ch. 1, Stormwater Management System Planning and Design, North Central Texas Council of Governments ***http://iswm.nctcog.org*** *Henrico County, Virginia Environmental Program Manual*, Ch. 9, Minimum Design Standards, 9.01, Energy Dissipater ***http://www.co.henrico.va.us/works/eesd***

Table 4.11. Stormwater Criteria for Ordinances and Design Guidance: Flood Control

<table>
<tr><th colspan="2">Criterion 5: Flood Control (FC) – Provide peak rate control for larger storms.</th></tr>
<tr><td>Explanation</td><td>Peak rates should be controlled in order to reduce downstream flooding. The standard depends on where a property is situated within a watershed and the design storms that typically cause flooding in the community. Flood control is customarily a local, regional, or state-driven criterion.

The Flood Control criterion can address one or both of the following, depending on community priorities:
▸ Overbank Flood Protection: Prevent nuisance flooding that damages downstream property and infrastructure.
▸ Extreme Flood Control: Maintain boundaries of the pre-development 100-year floodplain, and reduce risk to life and property from infrequent but extreme storms.

Waivers to the Flood Control criteria should be considered for:
▸ Discharges to large waterbodies
▸ Small sites (< 5 acres in size)
▸ Some redevelopment projects
▸ Sites subject to floodplain study that recommends alternative criteria
▸ Sites where on-site detention will cause a downstream peak flow increase compared to pre-development levels due to coincident peaks from the site and watershed

Communities should evaluate their existing flood control criteria to avoid costly over-control of peak rates that has marginal downstream benefits.</td></tr>
<tr><td>Potential Standards</td><td>Overbank (Minor Storm) Flood Protection:
The post-development peak rate of discharge for the 10-year, 24-hour storm must be reduced to the pre-development peak rate.

New structures or crossings within the floodplain must have adequate capacity for the ultimate (build-out) condition.

(NOTE: Minor storm flood control events vary around the country, usually ranging from the 2-year to the 10-year event.)

Extreme (Major Storm) Flood Control:
The post-development peak rate of discharge for the 100-year, 24-hour storm must be reduced to the pre-development peak rate.

(NOTE: Major storm flood control events vary around the country, usually ranging from the 25-year to the 100-year event.)</td></tr>
<tr><td>Candidate BMPs to Meet Standards</td><td>▸ Ponds and pond/wetland systems that provide peak flow control
▸ Some underground structures
▸ As applicable, storage under parking lots or within ball fields, open space, etc.
▸ Floodplain and riparian management and restoration, preventing structures within the 100-year floodplain</td></tr>
<tr><td>Examples from Existing Programs – See Tool 5: Manual Builder for more examples and links</td><td>Georgia Stormwater Management Manual, Volume 2
http://www.georgiastormwater.com

Floodplain Management Association
http://www.floodplain.org</td></tr>
</table>

Table 4.12. Stormwater Criteria for Ordinances and Design Guidance: Redevelopment

Criterion 6: Redevelopment – Provide flexibility to meet criteria for redevelopment conditions.	
Explanation	Redevelopment projects can present unique stormwater challenges due to existing hydrologic impacts, compacted soils, generally small size and intensive use, and other factors. Local programs should examine flexible standards for redevelopment, so that stormwater requirements do not act as a disincentive for desirable redevelopment projects. This is especially important within designated redevelopment zones, downtown revitalization zones, enterprise zones, brownfield sites, and other areas where infill and redevelopment is promoted through local policies and incentive programs. At the same time, redevelopment offers a unique opportunity to achieve incremental water quality and/or drainage improvements in previously developed areas where stormwater controls might be few or nonexistent. Redevelopment is one of the few chances to address existing impairments.
Potential Standards	Redevelopment projects must use one or a combination of the following approaches for stormwater compliance: ► Reduce existing impervious cover by at least 20%. ► Provide runoff reduction and water quality treatment (Criteria 2 and 3) for at least 30% of the site's existing impervious cover and any new impervious cover. ► Use innovative approaches to reduce stormwater impacts across the site. Examples include green roofs and pervious parking materials. The local program can exercise flexibility with regard to sizing and design standards for sites that are attempting to place new practices into a site with existing drainage infrastructure. ► Provide equivalent stormwater treatment at an off-site facility. ► Address downstream channel and flooding issues through channel restoration and/or off-site remedies. ► Contribute to a watershed project through a fee-in-lieu payment.
Candidate BMPs to Meet Standards	► See T**ables 4.7** through **4.11** for various stormwater criteria ► Off-site mitigation may also include stream or wetland restoration, stormwater retrofits, and regional stormwater solutions
Examples from Existing Programs – See Tool 5: Manual Builder for more examples and links	*City of Philadelphia Stormwater Management Guidance Manual*, Ch. 2, Applicability and Approval ***http://www.phillyriverinfo.org*** *Critical Area 10% Rule Guidance Manual*, Maryland Critical Area Commission ***http://www.dnr.state.md.us/criticalarea/guidancepubs*** *Developments Protecting Water Quality: A Guidebook of Site Design Examples*, Santa Clara Valley Urban Runoff Pollution Prevention Program ***http://scvurppp-w2k.com/Default.htm***

Table 4.13. Special Stormwater Criteria for Lakes and Water Supply Reservoirs

Urban watersheds can produce higher unit area nutrient loads from stormwater runoff compared to other watersheds (**Caraco and Brown, 2001**). Therefore, special stormwater criteria might be needed if the receiving waters in urban watersheds are sensitive to excess nutrients. Nutrient-sensitive waters include lakes, water supply reservoirs, estuaries, and coastal areas.

Several state, regional, and local stormwater programs have developed special stormwater design criteria for nutrient-sensitive waters that require development activities to create *no net increase* in pollutant loads from the pre-development condition ***or*** to meet site-based load limits (e.g., no more than 0.28 pound/acre/year of total phosphorus). These criteria focus on achieving this goal using site design techniques and stormwater BMPs with a proven rate of pollutant removal efficiency.

If a designer cannot meet the total removal requirement on-site, the site owner can be allowed to pay an offset fee for the difference. This fee is set as the cost of removing an equivalent amount of pollutants elsewhere in the watershed.

Several states that require stormwater pollutant load reduction to protect sensitive waters are listed below.

Maine:	To protect sensitive lakes
New York:	To protect unfiltered surface water supply
VA/MD:	To reduce nutrients delivered to Chesapeake Bay from shoreline development
Minnesota:	To protect sensitive lakes

Photo courtesy of U.S. Army Corps of Engineers

For detailed guidance, consult the following resources:

Maine Stormwater Best Management Practices Manual, Volume II, *Phosphorus Control in Lake Watersheds: A Technical Guide to Evaluating New Development*
http://www.maine.gov/dep/blwq/docstand/stormwater/stormwaterbmps

Minnesota Stormwater Manual, Ch. 10, Unified Stormwater Sizing Criteria (Section 9, Lakes)
http://www.pca.state.mn.us/water/stormwater

Table 4.14. Special Stormwater Criteria for Trout and Salmon Streams

Several state and local stormwater programs have developed special stormwater design criteria to protect trout and salmon streams. Trout and salmon populations are extremely sensitive to stream habitat degradation, stream warming, sedimentation, stormwater pollution, and other impacts associated with development. In addition, some poorly designed or located stormwater BMPs can induce stream warming that can harm trout or salmon populations. Without special design criteria, these sensitive water resources might not be adequately protected from problems associated with stormwater runoff.

Some common examples of special design criteria aimed at protecting trout and salmon streams include:

- Requiring the protection and/or restoration of riparian forest buffers
- Requiring groundwater recharge and/or runoff reduction
- Requiring downstream channel protection at development sites (although extended detention times should be limited to less than 12 hours)
- Restrictions on the use of stormwater ponds and wetlands that can cause stream warming
- Preference toward the use of infiltration and bioretention practices
- Requiring that stormwater BMPs be constructed "off-line" so they are located away from the stream
- Requiring that pilot channels, outflow channels, and pools be shaded with trees and shrubs
- Requiring that stormwater BMPs be planted with trees to maximize forest canopy cover
- Requiring that stormwater BMPs be located away from the streamside forest buffer to maximize forest canopy cover and shading in riparian areas
- Requiring pretreatment of roadway runoff to reduce sediment and road salt and sand discharges to receiving streams

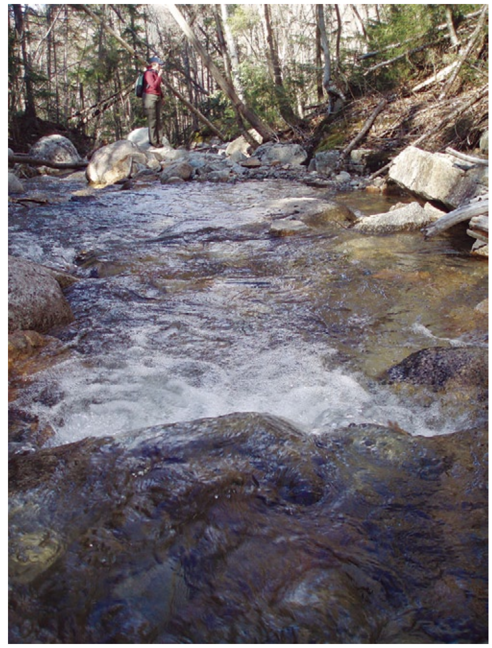
Individual stormwater BMP design specifications can also be modified to prevent:

Large, unshaded permanent pools or shallow wetland areas

Extended detention times that are longer than 12 hours

Extensive riprap or concrete channels

Construction of BMPs in on-line or in-stream configurations



Graphic courtesy of Tim McCabe

Photo courtesy of U.S. Fish & Wildlife Service

Photo courtesy of U.S. Fish & Wildlife Service

For more information, see the North Carolina State University publication *Stormwater BMPs for Trout Waters* (Jones and Hunt, 2007) ***http://www.bae.ncsu.edu/stormwater/pubs.htm***

Dane County, Wisconsin, Erosion Control and Stormwater Management Manual, Ch. 3, Stormwater (Section 3.8, Thermal Control) (2007) ***http://www.danewaters.com/business/stormwater.aspx***

Table 4.15. Special Stormwater Criteria for Groundwater

Groundwater is a critical water resource because many residents depend on groundwater for their drinking water and the health of many aquatic systems depends on steady recharge. For example, during periods of dry weather, groundwater sustains flows in streams and helps to maintain the hydrology of wetlands.

Because development creates impervious surfaces that prevent natural recharge, a net decrease in groundwater recharge rates can be expected in urban watersheds.

Communities that rely on groundwater as a drinking water supply have protected groundwater supplies and headwater streams by developing special criteria to require the infiltration of a certain volume of stormwater runoff and require the use of pretreatment for all stormwater BMPs. They have also required the use of low-impact development techniques, such as impervious disconnection, soil amendments, open space protection, and/or the maintenance or restoration of a certain amount of "recharge-friendly" land cover, especially forest.

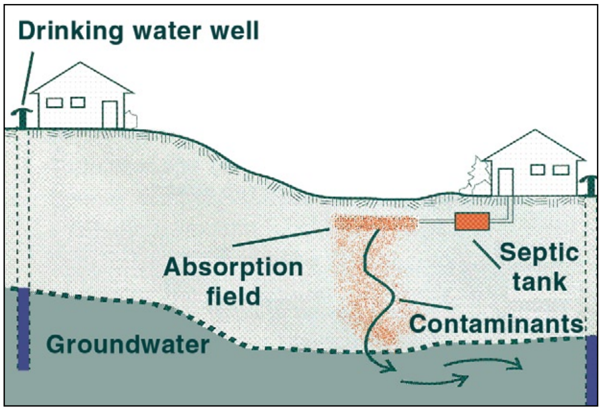
However, runoff from urban land uses and activities can degrade groundwater quality if it is directed into the soil without adequate treatment. Soluble pollutants, such as chloride, nitrate, copper, dissolved solids, and hydrocarbons can migrate into groundwater and potentially contaminate groundwater supplies. Communities should take care to ensure that groundwater supplies are both maintained with groundwater recharge and protected from contamination.

The list below contains examples of "stormwater hotspots." At these types of sites, infiltration should be discouraged and source control and pollution prevention measures adopted to minimize spills, leaks, and illicit discharges.

For examples of stormwater criteria and standards to protect groundwater, see **Tool 5: Manual Builder**.

Potential Stormwater Hotspots (**CWP and MDE, 2000**)

- Vehicle salvage yards and recycling facilities
- Outdoor vehicle service and maintenance facilities
- Outdoor vehicle and equipment cleaning facilities
- Fleet storage areas (bus, truck, etc.)
- Industrial sites
- Marinas (service and maintenance)
- Outdoor liquid container storage
- Some outdoor loading/unloading facilities
- Public works storage areas
- Commercial container nursery
- Large chemically managed turf areas



Graphic courtesy of Nick Evans

Table 4.16. Special Stormwater Criteria for Wetlands

Wetlands are recognized for the many important watershed functions and services they perform, and their direct disturbance is closely regulated. However, indirect impacts associated with stormwater, such as altered water level fluctuations and increased nutrient and sediment loads, are not routinely regulated or even acknowledged. Stormwater inputs can alter the hydrology, topography, and vegetative composition of wetlands **(Wright et al. 2006)**. For example, increased frequency and duration of inundation can degrade native wetland plant communities or deprive them of their water supply. The deposition of sediment carried by urban stormwater can have the same effect, causing replacement of diverse species with monotypes of reed canary grass or cattails.

Cappiella et al. (2005) have developed a framework for protecting sensitive natural wetlands, including special stormwater criteria for discharges to wetlands. This information can be found at the Center for Watershed Protection's Wetlands Web Site:
www.cwp.org > Resources > Special Resource Management > Wetlands & Watersheds

Photo courtesy of U.S. Fish & Wildlife Service

Table 4.17. Special Stormwater Criteria for Impaired (TMDL-Listed) Waters

Under the Clean Water Act, water quality standards, which consist of both narrative and numeric criteria, are established to protect the physical, chemical, and biological integrity of surface waters and maintain designated uses. If water quality monitoring indicates that these water quality standards are not being met and that designated uses are not being achieved, surface waters may be added to a list of impaired waters.

When a surface water is listed, a Total Maximum Daily Load (TMDL) study and implementation plan are scheduled for development. Using water quality sampling and computer modeling, a TMDL study establishes pollutant load reductions from both point and nonpoint sources needed to meet established water quality standards.

There is increasing emphasis among state and federal permitting agencies to create stronger links between TMDLs and stormwater permits, such as MS4 permits (**USEPA, 2007; USEPA Region 5, 2007a, 2007b**). With successive rounds of MS4 permits, permitted agencies will very likely need to apply more stringent stormwater criteria in impaired watersheds and/or provide a better match between particular pollutants of concern and selected BMPs.

Strategies for Local Stormwater Managers to Address TMDLs Through Special Stormwater Criteria

Depending on the nature of the TMDL and the implementation plan, local stormwater criteria can help address TMDL requirements. The following three general approaches are discussed in order of decreasing sophistication. There are other approaches that can applied, and a local program may find that a hybrid approach is most applicable.

- Site-Based Load Limits
- Surrogate Measures for Sources of Impairment
- Presumptive BMP Performance Standards

1. Site-Based Load Limits

Some pollutants that are the basis for TMDLs are understood well enough that site-based load calculations can be done for each development and redevelopment site. These pollutants generally include sediment, phosphorus, and nitrogen (in some areas, other pollutants, such as ammonia, fecal coliform bacteria, and other pollutants can be added to the list if adequate local or regional studies have been conducted) (**MSSC, 2005**). If site-based load limits are to be used, the TMDL and local stormwater program should have the following characteristics:

- The TMDL allocates a load reduction target to urban/developed land (preferably separating out existing developed land from estimates of future developed land).
- The local program uses (or plans to use) a method, such as the Simple Method (**CWP and MDE, 2000**), that allows for the calculation of pollutant loads for a particular site development project.
- The local, regional, or state manual (or policy document) contains a method to assign pollutant removal performance values to various structural and nonstructural BMPs. Low-Impact Development (LID) credits are another positive factor so that LID practices can be incorporated.

The general process for calculating site-based load limits is as follows:

1. Based on the wasteload allocation (WLA) and load allocation (LA) in the TMDL, develop a site-based load limit for the pollutant of concern. The local program must allocate the total load reduction goal for urban/developed land to existing and future urban/developed land within the impaired watershed. The program should consider having a more flexible standard for redevelopment projects because the standard will usually be more difficult to meet for these projects.

   Example: Site-based load limit = 0.28 pounds/acre/year for total phosphorus (***Hirschman et al. 2008***)

   That is, if each newly developed site meets the standard of 0.28 pound/acre/year, the load reduction goal for new urban/developed land can be met.

   In this context, other measures—such as stormwater retrofits and restoration projects—might have to be applied for existing urban/developed land (see Step 5 below and ***Schueler et al. 2007****).*

2. For each development site, the applicant should calculate the post-development load for the pollutant of concern using a recognized model or method. Most use impervious cover as the main basis for calculating loads, although other land covers (e.g., managed turf) are also important contributing sources.

   Example: Post-development total phosphorus load = 0.55 pound/acre/year

Table 4.17. Special Stormwater Criteria for Impaired (TMDL-Listed) Waters *(continued)*

3. Next, the required load reduction is computed by comparing the post-development load to the site-based load limit, and an appropriate BMP is selected.

   Example: Load reduction = post-development load – site-based load limit

   0.55 – 0.28 = 0.27 pound/acre/year (load that must be removed to meet the load limit standard)

   Selected BMPs should be capable of removing the target load reduction. One way to determine this is to calculate the load leaving the BMP based on the expected effluent concentration and the effluent volume for the design storm (or on an annual basis).

4. Select a combination of structural and nonstructural BMPs that can be documented to meet the required load reduction. If the local program and/or TMDL implementation plan encourages LID, then these practices should be assigned load reduction credits (see **Section 6.10**).

5. If the entire load reduction cannot be achieved (or is impractical) on the particular site, the applicant might be eligible to implement equivalent off-site BMPs within the impaired watershed. These off-site BMP may be implemented by the applicant on developed land that is currently not served by stormwater BMPs. Alternatively, the applicant can pay an appropriate fee (fee in lieu) to the local program to implement stormwater retrofits within the impaired watershed. In either case, full on-site compliance is being "traded" to implement other BMPs that can help achieve TMDL goals.

The local program would have to apply this technique to a variety of local plans to gauge achievability and feasibility across a range of development scenarios.

A good real-world example of this approach (although not specific to impaired watersheds) is Maine's *Phosphorus Control in Lake Watersheds: A Guide to Evaluating New Development* (Interim Draft, 12/10/2007).
http://www.maine.gov/dep/blwq/docstand/stormwater/stormwaterbmps

2. Surrogate Measures for Sources of Impairment

If site-based load limits cannot be used because of the type of impairment (e.g., aquatic life) or limited data, surrogates that have a strong link to the cause of impairment can be used. For instance, various TMDLs have used impervious cover and stormwater flow as surrogates for stormwater impacts on aquatic life, stream channel stability, and habitat (**USEPA, 2007**). In these cases, the surrogates are relatively easy to measure and track through time. The TMDL might have a goal to reduce impervious cover and/or to apply BMP treatment to a certain percentage of impervious cover within the impaired watershed.

A local stormwater program could apply the surrogate approach through a tiered implementation strategy for new development and redevelopment (see also **Section 4.2**):

- FIRST, minimize the creation of new impervious cover at the site through site design techniques. Preserve sensitive site features, such as riparian areas, wetlands, and important forest stands.
- SECOND, disconnect impervious cover by using LID and nonstructural BMPs.
- THIRD, install structural BMPs to reduce the impact of impervious cover on receiving waters.

3. Presumptive BMP Performance Standards

Perhaps the most widespread and simplest method to link TMDL goals with stormwater criteria is to presume that implementation of a certain suite of BMPs will lead to load reductions, and that monitoring and adaptive management can help adjust the appropriate template of BMPs over time (**USEPA, 2007**; **USEPA Region 5, 2007a**). This strategy acknowledges that data are often too limited to draw a conclusive link between particular pollutant sources and in-stream impairments. However, as more data become available and TMDL implementation strategies are refined, a more quantitative method, such as the two noted above, should be pursued.

There are a wide variety of "presumptive" BMPs that can be included in local stormwater criteria for an impaired watershed, and these should be adapted based on the pollutant(s) of concern:

- Stream/wetland/lake setbacks and buffers
- Site reforestation
- Soil enhancements
- Incentives for redevelopment

Table 4.17. Special Stormwater Criteria for Impaired (TMDL-Listed) Waters *(continued)*

- Requirements for runoff reduction (see **Table 4.8**)
- Implementation of LID
- Requirements for BMPs with filter media and/or vegetative cover
- Enhanced sizing and/or pre-treatment requirements
- Required BMPs at stormwater hotspots or particular land use categories (e.g., marinas, industrial operations)
- Contribution to stormwater retrofit projects within the watershed

The providing channel protection criterion (see **Table 4.10**) is highly recommended for receiving waters that are impaired by sediment or sediment-related pollutants. Given the importance of channel erosion in the sediment budget of urban streams, it is critical to control erosive flows from development projects.

For more information on linking TMDLs to stormwater permits, see:
Total Maximum Daily Loads with Stormwater Sources: A Summary of 17 TMDLs, EPA 841-R-07-002
http://www.epa.gov/owow/tmdl

Total Maximum Daily Loads and National Pollutant Discharge Elimination System Stormwater Permits for Impaired Waterbodies: A Summary of State Practices, USEPA Region 5
http://www.epa.gov/R5water/wshednps/topic_tmdls.htm

Linking TMDLs and the Implementation of Low Impact Development/Green Infrastructure Practices, USEPA Region 5

For a comprehensive primer on stormwater retrofitting in existing urban/developed land, see:
Urban Stormwater Retrofit Practices, Manual 3, Urban Subwatershed Restoration Manual Series, Center for Watershed Protection, ***www.cwp.org*** > Resources > Controlling Runoff & Discharges > Stormwater Management > National/Regional Guidance.