2004 Connecticut Stormwater Quality Manual

by
The Connecticut Department of Environmental Protection

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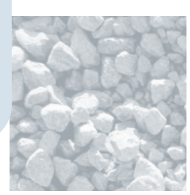

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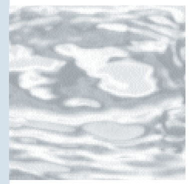

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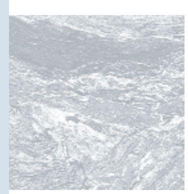

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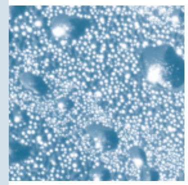

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Chapter 1
Introduction to the Stormwater Quality Manual

Volume 1: Background

Chapter 1 Introduction

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1.1 Purpose of the Manual

The purpose of this Manual is to provide guidance on the measures necessary to protect the waters of the State of Connecticut from the adverse impacts of post-construction stormwater runoff. The guidance provided in this Manual is applicable to new development, redevelopment, and upgrades to existing development. The Manual focuses on site planning, source control and pollution prevention, and stormwater treatment practices. Related topics such as erosion and sediment control, stormwater drainage design and flood control, and watershed management are addressed in the Manual as secondary considerations. The Manual does not address agricultural runoff. Additional information on these topics can be found in other related guidance documents listed at the end of this chapter.

1.2 Users of the Manual

The Connecticut Department of Environmental Protection intends this Manual for use as a planning tool and design guidance document by the regulated and regulatory communities involved in stormwater quality management in the State of Connecticut. The Manual provides uniform guidance for developers and engineers on the selection, design, and proper application of stormwater Best Management Practices (BMPs). The Manual will also assist local and state government officials (i.e., town engineers, planners, Planning and Zoning Commissions, Conservation Commissions, Inland Wetlands Commissions, and Connecticut State agencies) design and review projects in a technically sound and consistent manner.

The information and recommendations in this Manual are provided for guidance and are intended to augment, rather than replace, professional judgement. The design practices described in this Manual should be implemented by individuals with a demonstrated level of professional competence, such as professional engineers licensed to practice in the State of Connecticut. Design engineers, as well as those responsible for operation and maintenance, are ultimately responsible for the long-term performance and success of these practices. However, the use of this Manual is not restricted to engineers or technical professionals. It is also intended to be used by other individuals involved in stormwater and land use management for reviewing and recommending practices contained in the Manual.

1.3 Organization of the Manual

The Manual is organized into two volumes, both contained in a single, comprehensive document. The organization of the Manual generally follows the recommended stormwater management planning process, which emphasizes preventive measures such as site planning and alternative site design, source controls, and pollution prevention over end-of-pipe structural controls.

Volume I provides an overview of the stormwater problem, approaches for preventing and mitigating stormwater impacts, and a description of site planning and source control practices for pollution prevention. The subsequent chapters in Volume I include:

***Chapter Two* – Why Stormwater Matters: The Impacts of Urbanization**

This chapter introduces the concept of urban stormwater runoff and its impact on watershed hydrology, water quality, and ecology. Chapter Two summarizes why stormwater management measures are necessary to protect receiving waters from the adverse impacts of uncontrolled stormwater runoff.

***Chapter Three* – Approaches for Preventing and Mitigating Stormwater Impacts**

Chapter Three presents an overview of approaches for preventing and mitigating stormwater impacts through site planning and pollution prevention, stormwater quantity controls, construction erosion and sedimentation controls, and post-construction stormwater quality management.

***Chapter Four* – Site Planning and Design**
Chapter Four addresses site planning concepts such as alternative site design and Low Impact Development. These techniques can be incorporated into the design of new projects to reduce or disconnect impervious surfaces and retain and infiltrate stormwater on-site, thereby eliminating or reducing the need for structural stormwater quality controls.

***Chapter Five* – Source Control Practices and Pollution Prevention**
Chapter Five describes source control and pollution prevention practices to limit the generation of stormwater pollutants at their source. This chapter focuses on common municipal, residential, commercial, and industrial practices applicable to new and existing development, such as street and parking lot sweeping, roadway deicing and salt storage, storm drainage system maintenance, illicit discharge detection and elimination, commercial and industrial pollution prevention, and lawn care and landscaping practices.

Volume II provides technical guidance on the selection, design, construction, and maintenance of structural stormwater treatment practices. Volume II also addresses procedures for developing a site stormwater management plan, and design issues associated with stormwater retrofits for existing development. Volume II includes the following chapters:

***Chapter Six* – Introduction to Stormwater Treatment Practices**
Chapter Six introduces structural stormwater treatment practices that can be used alone as primary treatment, as pretreatment or supplemental treatment practices, or in combination (i.e., treatment train approach). This chapter also describes general categories of recently developed, emerging, and potential future stormwater treatment devices and technologies, as well as criteria for evaluating the performance and applicability of new treatment practices.

***Chapter Seven* – Hydrologic Sizing Criteria for Stormwater Treatment Practices**
Chapter Seven explains the procedures and applicability of sizing criteria for structural stormwater treatment practices to meet pollutant reduction, groundwater recharge and runoff volume reduction, and peak flow control requirements. This chapter also includes guidance on the design of stormwater bypass structures and sizing examples for various types of stormwater treatment practices.

***Chapter Eight* – Selection Criteria for Stormwater Treatment Practices**
Chapter Eight provides guidance on selecting appropriate structural stormwater treatment practices for a development site based on the requirements and needs of the site. This chapter includes a recommended selection process and selection criteria.

***Chapter Nine* – Developing a Site Stormwater Management Plan**
Chapter Nine describes how to prepare a site stormwater management plan for review by local and state regulatory agencies. The chapter includes a recommended plan format and contents, and a completeness checklist for use by the plan preparer and reviewer.

***Chapter Ten* – Stormwater Retrofits**
Chapter Ten describes techniques for retrofitting existing developed sites to improve or enhance the water quality mitigation functions of the sites. Chapter Ten also discusses the conditions for which stormwater retrofits are appropriate and the potential benefits of stormwater retrofits.

***Chapter Eleven* – Design Guidance for Stormwater Treatment Practices**
Chapter Eleven provides detailed technical design guidance for each of the stormwater treatment practices introduced in Chapter Six. This chapter includes guidance on the design, construction, and maintenance of these practices, as well as summary information on selection and sizing criteria addressed in previous chapters.

Appendices
Appendices containing supplemental information on the design, construction, and maintenance of structural stormwater management practices are included at the end of Volume II. A glossary of terms used in the Manual is also provided in Appendix F.

While providing detailed guidance on a number of recommended stormwater management practices and related topics, this Manual is not an exhaustive reference on each topic and does not address all aspects of stormwater management. Additional technical guidance can be found in numerous other documents, many of which are referenced in this Manual. References and recommended additional sources of information are listed at the end of each chapter.

1.4 Regulatory Basis and Use of the Manual

This Manual is intended for use as a guidance document to assist developers and the regulated community in complying with existing local, state, and federal laws and regulations. The Manual itself has no independent regulatory authority. Rather, it establishes guidelines that are implemented through a framework of existing laws and regulations. Although this Manual is non-regulatory in scope, it provides the technical basis for a comprehensive, statewide stormwater quality management strategy, including the consistent application of stormwater management practices throughout the state.

1.5 Relationship of the Manual to Federal, State, and Local Programs

The Connecticut Department of Environmental Protection (DEP) historically has been a national leader in developing and implementing water quality protection programs and policies. A number of federal and state regulatory programs are currently in place for stormwater quality management and water resource protection in the state. Consistent with a long-established tradition of home-rule-style government exerted by municipal authorities, many of these programs are implemented at the local level through local zoning, subdivision, and inland wetlands and watercourses regulations and ordinances. In addition, the State of Connecticut has been delegated authority from the federal government to implement federal regulations that pertain to water resources protection. **Table 1-1** summarizes existing regulatory programs that address management of stormwater discharges in Connecticut. Descriptions of these programs and their relationship to this Manual are found in Section 1.5.2.

1.5.1 Federal Programs

Clean Water Act

The Federal Water Pollution Control Act of 1948, the first major federal legislation governing pollution of the nation's surface waters (33 U.S.C. 1251-1387), was significantly amended in 1972 (P.L. 92-500) and then again in 1977 when it became commonly known as the Clean Water Act (CWA) of 1977 (P.L. 95-217). The CWA was subsequently amended under the Water Quality Act of 1987 (P.L. 100-4). There are four primary sections of the CWA that relate to stormwater discharges:

- *Section 303 – Water Quality Standards and Implementation Plans*
- *Section 319 – Nonpoint Source Management Program*
- *Section 401 – Water Quality Certification*
- *Section 402 – National Pollutant Discharge Elimination System (NPDES)*

Under Section 303 of the CWA, states are required to adopt surface water quality standards, subject to review and approval by the U.S. EPA, and identify surface waters that do not meet these water quality standards following the installation of minimum required pollution control technology for point sources discharging to surface water bodies. These impaired water bodies must be ranked by the states and a Total Maximum Daily Load (TMDL) must be established for the pollutant(s) that exceed the water quality standards. A TMDL both specifies a maximum amount of pollutant that the surface water body can receive and allocates that amount, or load, among point and nonpoint sources, including stormwater discharges.

The Nonpoint Source Management Program was established under Section 319 of the CWA of 1987. Section 319 addresses the need for federal guidance and assistance to state and local programs for controlling nonpoint sources of pollution, including stormwater runoff. Under Section 319, states, territories and Indian Tribes receive federal grant money to support various activities that address nonpoint source pollution control. These activities include technical and direct financial assistance, education, training, technology transfer, demonstration projects, and monitoring to assess the effectiveness of specific nonpoint source implementation projects.

Section 401 of the CWA requires applicants for a federal license or permit to obtain a certification or waiver from the state water pollution control agency (DEP, or EPA for Indian reservation lands) for any activity which may result in a discharge into navigable waters of the state, including wetlands, watercourses, and natural and man-made ponds. This waiver certifies that the discharge will comply with the applicable provisions of the CWA and Connecticut's Water Quality Standards. Examples of federal licenses and permits for which water quality certification is required include U.S. Army Corps of Engineers Section 404 dredge and fill permits, Coast Guard bridge permits, and Federal Energy Regulatory Commission permits for hydropower and gas transmission facilities.

The NPDES program was established under Section 402 of the CWA and specifically targets point source discharges by industries, municipalities, and other facilities that discharge directly into surface waters. Stormwater discharges are addressed under the NPDES Stormwater Program. This two-phased national program targets non-agricultural sources of stormwater discharges that may adversely affect surface water quality. The NPDES permitting program is administered in Connecticut by DEP through a series of permits as outlined in **Table 1-1**. Phase I of the NPDES Stormwater Program was developed under the 1987 amendments to the CWA and regulates stormwater discharges from:

- *"Medium" and "large" municipal separate storm sewer systems (MS4s) located in incorporated places or counties with populations of 100,000 or more; and*
- *Eleven categories of industrial activity, one of which is construction activity that disturbs five or more acres of land.*

Phase II of the program expands the scope of the regulated discharges to include:

- *Certain regulated "small" MS4s; and*
- *Construction activity disturbing between one and five acres of land (i.e., small construction activities).*

The Phase II Final Rule was published in December 1999. DEP issued a General Permit in 2004 to address small municipalities. At the time of writing, DEP was in the process of developing a General Permit for the Connecticut Department of Transportation and other state and federal facilities with significant drainage systems and stormwater discharges. Stormwater discharges associated with construction activities between one and five acres are regulated by DEP through a coordinated effort with municipalities under the Connecticut Erosion and Sedimentation Control Act.

Coastal Zone Act Reauthorization Amendments

Section 6217 of the Coastal Zone Act Reauthorization Amendments (CZARA) of 1990 (16 U.S.C. §1455b) is designed to address the problem of nonpoint source pollution in coastal waters. Under Section 6217, states and territories with approved Coastal Zone Management Programs, including Connecticut, are required to develop Coastal Nonpoint Source Pollution Control Programs or face funding sanctions in both their coastal programs and their nonpoint programs established under Section 319 of the Clean Water Act. The program must describe how the state or territory will implement management measures to reduce or eliminate nonpoint source pollution, including stormwater runoff, to coastal waters. These management measures must conform to those described in the U.S. EPA publication *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters.*

1.5.2 State Programs

Connecticut Clean Water Act

The Connecticut Clean Water Act (CCWA) of 1967 (P.A. 67-57) launched Connecticut's modern water pollution control program. Under the CCWA, as amended, DEP has the regulatory authority to:

- *Abate, prevent or minimize all sources of water pollution, including nonpoint sources*
- *Develop state water quality standards*
- *Permit discharges, including stormwater discharges, to waters of the state*
- *Establish enforcement tools for pollution abatement and prevention*

This statute (Chapter 446k of the Connecticut General Statutes (CGS)) forms the authority for the DEP Bureau of Water Management's Permitting and Enforcement Division (PED) to regulate discharges to surface waters, ground waters, and Publicly Owned Treatment Works (POTWs). Discharges to surface waters are regulated by DEP under both the CCWA and the federal NPDES Program, because Connecticut has been delegated authority to implement the federal NPDES Program. Consequently, stormwater discharges are regulated under a series of general permits based on the type of activity generating the discharge. The general permit program is authorized under CGS §22a-430b and is designed to authorize similar minor stormwater discharges by one or more applicants. The regulated sources are divided into four major categories:

Commercial Activities: This general permit applies to discharges from any conveyance which is used for collecting and conveying stormwater and which is directly related to retail, commercial, and/or office services whose facilities occupy 5 acres or more of contiguous impervious surface and which are described in the SIC Codes 50's and 70's.

Industrial Activities: This general permit applies to discharges from any conveyance which is used for collecting and conveying stormwater and which is directly related to manufacturing, processing or material storage areas at designated categories of industrial facilities.

Construction Activities: This general permit applies to discharges of stormwater and dewatering wastewaters from construction activities which include, but are not limited to, clearing, grading, and excavating and which result in the disturbance of 5 or more acres of total land area on a site. As described above, under Phase II of the NPDES Stormwater Program, construction activities disturb-

Table 1-1 Existing Stormwater Management Programs in Connecticut

Program/ DEP Contact	Programs Goals	Stormwater Regulation	Regulates Quantity	Regulates Quality	State or Local Regulations (Authorizing Statute)	Regulation of New or Existing Facilities[1]
Commercial General Permit PED Stormwater (860) 424-3018	Regulates stormwater discharges from commercial activity	Requires permits from a commercial activity with 5 or more acres of contiguous impervious surfaces	No	Yes	State (CGS §§22a-416 through 22a-438)	Both
Industrial General Permit PED Stormwater (860) 424-3018	Regulates stormwater discharges from industrial activities	Requires permits for facilities having a stormwater discharge associated with industrial activity	No	Yes	State (CGS §§22a-416 through 22a-438)	Both
Construction General Permit PED Stormwater (860) 424-3018	Regulates stormwater discharges from construction activity	Requires permits from construction activities disturbing more than 5 total acres land area (projects disturbing 1 to 5 acres regulated at the local level under NPDES Phase II)	No	Yes	State (CGS §§22a-416 through 22a-438)	Both
Phase II General Permits PED Stormwater (860) 424-3018	Regulates stormwater discharges from municipal, state, and other designated stormwater drainage systems in urbanized areas	Requires municipalities and other entities to develop and implement a stormwater management program consisting of minimum control measures	Yes	Yes	State (CGS §§22a-416 through 22a-438)	Both
Inland Wetlands and Watercourses Act IWRD (860) 424-3019	Protects and regulates activities in inland wetlands, watercourse, and adjacent areas	Considers impacts to wetlands from stormwater or stormwater-related activities	Yes	Yes	State and Local (CGS §§22a-36 though 22a-45a)	Both
Erosion and Sediment Guidelines IWRD (860) 424-3019	Provides guidance on erosion controls	Guidelines for control of stormwater during construction	Yes	Yes (sediment)	State and Local (CGS §§22a-325 through 22a-329)	New
Flood Management IWRD (860) 424-3019	Regulates state actions in floodplains and changes in drainage patterns	Requires careful planning and siting of development projects and modifications to flood control facilities	Yes	Yes	State (CGS §§25-68b through 25-68h)	Both
Stream Channel Encroachment program IWRD (860) 424-3019	Regulates activities in certain floodplains	Considers impacts to wetlands and watercourses from storm water or stormwater-related activities	Yes	Yes	State (CGS §§22a-342 through 22a-349a)	Both
401 Water Quality Certification IWRD (860) 424-3019	Regulates activities which require a federal license or permit for discharge into navigable waters of the state	Requires certification from DEP that the discharge will comply with the Federal Water Pollution Control Act and Connecticut Water Quality Standards	No	Yes	State/Federal (33 USC 1341)	Both
Water Diversion IWRD (860) 424-3019	Regulates withdrawal and use of groundwater and surface waters of the state, including stormwater diversions	Requires permitting for any activity that causes, allows, or results in the withdrawal from or the alteration, modification, or diminution of the instantaneous flow of water, including stormwater	Yes	Yes	State (CGS §§22a-365 through 22a-379a)	Both
Dam Safety IWRD (860) 424-3706	Regulates construction, alteration, and repair of dams, including stormwater impoundments	Requires registration and potentially permit approval/inspection for new stormwater impoundments (ponds, wetlands, infiltration basins, etc.)	No	No	State (CGS §§22a-401 through 22a-411)	Both

Table 1-1 Existing Stormwater Management Programs in Connecticut *(con't)*

Program/ DEP Contact	Programs Goals	Stormwater Regulation	Regulates Quantity	Regulates Quality	State or Local Regulations (Authorizing Statute)	Regulation of New or Existing Facilities[1]
Coastal Management Act OLISP (860) 424-3034	Protects coastal resources and supports water-dependent uses	Regulates development that impacts coastal water and resources	Yes	Yes	State and Local (CGS §§22a-90 through 22a-112)	Both
Tidal Wetlands Act OLISP (860) 424-3034	Requires permits for dredging, draining, or filling within tidal wetlands	Discourages direct stormwater discharges	Yes	Yes	State (CGS §§22a-28 through 22a-35)	Both
Structures Dredging and Fill Act OLISP (860) 424-3034	Requires permits for structures, dredging, or fill in tidal, coastal, or navigable waters	Discourages direct stormwater discharges	Yes	Yes	State (CGS §§22a-359 through 22a-363f)	Both
Nonpoint Source Management Program PSD (860) 424-3020	Coordinates statewide efforts to prevent and manage nonpoint source pollution	Relies on existing regulations in place at federal, state, and local level	No	No	State	Both
Aquifer Protection Program PSD (860) 424-3020	Addresses potential groundwater contamination through various programs to ensure safe drinking water supplies	Management plans may include stormwater controls	No	Yes	State and Local (CGS §§22a-354a through 22a-354b)	Both
Source Water Assessment Program BWM/DPH (860) 424-3704	Assessment and protection of public drinking water supply sources	Requires assessment of delineated protection areas of potential sources of contamination. Relies primarily on existing regulations.	No	No	State and Federal	Both
Underground Injection Control Program BWM (860) 424-3018	Prohibits the use of Class V wells and limits the use of UIC drywells in existing or potential groundwater drinking supply areas	Requires safeguards for infiltration of stormwater in areas with high potential for spills and groundwater drinking supply areas	No	Yes	State and Federal	Both
Public Health Code – Sanitation of Watersheds DPH	Protects public water supply sources	Regulates stormwater discharges within 100 feet of an established watercourse within public water supply watersheds or groundwater aquifer recharge areas	Optional	Yes	PHC 19-13-B32i	New
Municipal Planning and Zoning Authorities	Reviews site development plans and protects environmental resources	Considers impacts to receiving waters	Optional	Optional	Local	Both

[1]Refers to whether the program primarily applies to newly constructed facilities or new development (New), existing facilities or development (Existing), or both.

PED – Permitting and Enforcement Division, IWRD – Inland Water Resources Division, OLISP – Office of Long Island Sound Programs, PSD – Planning and Standards Division, BWM – Bureau of Water Management, DPH – Department of Public Health, CGS – Connecticut General Statutes ing between one and five acres are also regulated by DEP through a coordinated effort with municipalities under the Connecticut Erosion and Sedimentation Control Act.

Municipal Separate Storm Sewer Systems (MS4s): This general permit regulates discharges of stormwater from small MS4s and other similar facilities located in urbanized areas. Separate general permits address stormwater discharges from small municipalities and other state and public facilities, as well as the Connecticut Department of Transportation.

Inland Wetlands and Watercourses Act

The Inland Wetlands and Watercourses Act of 1972, as amended, establishes authority for DEP and municipalities to adopt programs regulating construction and other activities affecting inland wetlands and watercourses, including impacts due to stormwater or stormwater-related activities. The Wetlands Management Section of the DEP Inland Water Resources Division (IWRD) has responsibility for overseeing implementation of the Act and directly regulates the activities of Connecticut state agencies that are located in, or may affect, inland wetlands and watercourses. As discussed in more detail below, local inland wetland agencies are responsible for regulating private and municipal work located in, or affecting, wetlands or watercourses within each Connecticut municipality.

Soil Erosion and Sediment Control Act

The Soil Erosion and Sediment Control Act (CGS §§22a- 325 to 22a-329, inclusive) requires that the Council on Soil and Water Conservation develop guidelines for soil erosion and sediment control on land being developed. The latest version of these guidelines was released in April of 2002. The goal of the guidelines is to reduce soil erosion from stormwater runoff, minimize nonpoint sediment pollution from land being developed, and conserve and protect the land, water, air and other environmental resources of the state.

Flood Management Certification

Under CGS §§25-68b through 25-68h, inclusive, any state agency proposing an activity within or affecting a floodplain or impacting natural or man-made storm drainage facilities must submit a flood management certification application to DEP.

Stream Channel Encroachment

Stream channel encroachment lines have been established for approximately 270 linear miles of riverine floodplain throughout Connecticut. Under CGS §§22a-342 through 22a-349a, DEP IWRD regulates the placement of encroachments and obstructions riverward of these encroachment lines. Any activity that permanently alters the character of the floodplain or watercourse within these areas, including activities generating stormwater discharges, is subject to approval by DEP.

401 Water Quality Certification

Applicants for a federal license or permit for activities that may result in a discharge into navigable waters of the state, including stormwater discharges, must submit a water quality certification application to DEP.

Water Diversion Policy Act

The Water Division Policy Act of 1982 (P.A. 82-402, as amended) grants the DEP IWRD limited authority to regulate the withdrawal and use of groundwater and surface waters of the state, including stormwater diversions. Under CGS §§22a-365 through 22a-379a, permitting is required for any activity that causes, allows, or results in the withdrawal from, or the alteration, modification, or diminution of, the instantaneous flow of water. Diversions must be consistent with other state policies that deal with long-range planning, management and use of the water resources of the state, including the State Plan for Conservation and Development, Water Quality Standards, Flood Management Act, Water Supply Planning Process, Inland Wetlands and Watercourses Act, Aquifer Protection Act, and Endangered Species Act.

Dam Safety Program

The Dam Safety Section of the DEP IWRD is responsible for administration and enforcement of Connecticut's dam safety laws under CGS §§22a-401 through 22a-411, inclusive. The Dam Safety Section regulates the construction, alteration, repair, and removal of dams, including stormwater impoundments through the use of embankments such as stormwater retention/detention ponds, stormwater wetlands, and infiltration basins. Registration with the Dam Safety Section is required for all new stormwater impoundments. A dam construction permit may also be required if the structure may endanger life or property in the event of failure or breaking away. Structures that pose a significant or high hazard to life or property are also subject to periodic inspections by DEP.

Connecticut Coastal Management Act

The Connecticut Coastal Management Act (CGS §§22a-90 through 22a-112, inclusive) establishes goals and policies for the protection of coastal resources. Under CGS §22a-98, the Commissioner of DEP must coordinate all regulatory programs under his jurisdiction with permitting authorities in the coastal area, including those related to wetlands and watercourses, stream channel encroachment, and the erection of structures or placement of fill in tidal, coastal, or navigable waters, to ensure that permits issued under such regulatory authority are consistent with coastal management goals and policies. The coastal area is defined by statute (CGS §22a-94(a)) and encompasses the municipalities listed in Table 1-2. In addition, pursuant to CGS §22a-100(b), each state department, institution, or agency responsible for the primary recommendation or initiation of actions within the coastal boundary which may significantly affect the environment must also ensure that such actions are consistent with coastal management goals and policies and incorporate all reasonable measures mitigating any adverse impacts on coastal resources. The coastal boundary is defined by statute (CGS §22a-94(b)). Adverse impacts on coastal resources are also statutorily defined (CGS §22a-93(15)) and include degrading water quality through the significant introduction into either coastal waters or groundwater supplies of suspended solids, nutrients, toxics, heavy metals, or pathogens, all of which can be contained in stormwater. In addition, degrading water quality through the significant alteration of temperature, pH, dissolved oxygen, or salinity is also included in the statutory definition of adverse impacts, and these impacts can also result from stormwater runoff. Coastal permitting and assistance to municipalities is administered through the DEP Office of Long Island Sound Programs (OLISP).

Tidal Wetlands Act

The Tidal Wetlands Act of 1969 (CGS §§22a-28 through 22a-35, inclusive) gives DEP authority to regulate activities in tidal wetlands. The permitting program administered by OLISP requires that the applicant address possible impacts to coastal resources, including those associated with stormwater runoff, and discourages direct stormwater discharges to tidal wetlands.

Structures, Dredging and Fill Act

The Structures, Dredging, and Fill Act (CGS §§22a-359 through 22a-363f, inclusive) gives DEP the authority to regulate dredging, the erection of structures, and the placement of fill in tidal, coastal or navigable waters of the state waterward of the high tide line. The permitting program administered by OLISP requires that the applicant address possible impacts to coastal resources, including those associated with stormwater runoff, and discourages direct untreated stormwater discharges to tidal, coastal, or navigable waters.

Nonpoint Source Management Programs (pursuant to CWA Section 319 and CZARA Section 6217)

The Connecticut Nonpoint Source Management (NPS) Program is administered by the DEP Bureau of Water Management (BWM) Planning and Standards Division (PSD) and is a network of several federal, state, and local programs. The NPS Program includes all of the components required under Section 319 of the Federal Clean Water Act. It establishes long- and short-term goals for the prevention and management of nonpoint sources of pollution, including those associated with urban runoff and stormwater. EPA defines NPS pollution as that which is "caused by diffuse sources that are not regulated as point sources and are normally associated with precipitation and runoff from the land or percolation." EPA approved Connecticut's upgraded Nonpoint Source Management Program in November 1999 (see Nonpoint Source Management Program at http://www.dep.state.ct.us/wtr/nps/npsmgtpl.pdf).

As described in the discussion of federal programs above, Section 6217 of the 1990 CZARA requires the development of a Coastal Nonpoint Pollution Control Program (CNPCP) to implement management measures to reduce or eliminate nonpoint source pollution within the coastal boundary. The CNPCP is a networked program administered by OLISP with assistance from BWM and relies on other regulatory programs described in this section including state and local permitting authorities.

Aquifer Protection Area Act

The Aquifer Protection Area Act of 1989 requires the development of aquifer protection land use regulations applicable within DEP-approved aquifer protection areas (areas recharging large public water supply wells). As part of the regulations, issued in 2004, municipalities containing aquifer protection areas are required to adopt regulations, subject to approval by DEP, requiring permitting for all regulated activities within aquifer protection areas. In addition, regulated activities within an aquifer protection area may require a stormwater management plan to assure that stormwater runoff generated by the proposed activity is managed in a manner to prevent pollution of ground water.

Source Water Assessment Program (SWAP)

The Connecticut Source Water Assessment Program (SWAP) was initiated in 1997 in response to the 1996 Amendments to the Federal Safe Drinking Water Act. The Connecticut Department of Public Health (DPH), in partnership with DEP, is responsible for the development of the SWAP, which is designed to assess and protect public drinking water supply sources in the state. The SWAP completes its work based upon an EPA-approved Work Plan dated September 1999. The SWAP includes the delineation of a protection area surrounding the drinking water source, the identification of potential pollution sources within and around the protection area, and the determination of a water supply's susceptibility to contamination. The SWAP will build on existing surface water and wellhead protection programs administered by DPH and DEP. As part of the program, DEP and DPH will recommend a variety of source protection strategies aimed

Table 1-2
Municipalities Within The Coastal Area

Branford	Groton Long Point	Norwich
Bridgeport	Guilford	Old Saybrook
Chester	Hamden	Old Lyme
Clinton	Ledyard	Orange
Darien	Lyme	Preston
Deep River	Madison	Shelton
East Haven	Milford	Stamford
East Lyme	Montville	Stonington (Borough and Town of)
Essex	New London	Stratford
Fairfield	New Haven	Waterford
Fenwick	Noank	West Haven
Greenwich	North Haven	Westbrook
Groton (City and Town of)	Norwalk	Westport

at reducing potential impacts from non-point pollution sources including stormwater runoff to municipalities and water companies. Additional information on the SWAP can be found at http://www.dph.state.ct.us/BRS/WSS/swap_reports. htm.

Underground Injection Control (UIC) Program

The Federal Safe Drinking Water Act established the UIC program to provide safeguards so that injection (or infiltration) wells used for waste disposal do not endanger water quality, especially groundwater drinking sources. In Connecticut, the DEP Water Management Bureau has been given primacy for this program. A well under the UIC Program is any well whose depth is greater than the largest surface dimension (this could include certain infiltration trenches with vertical pipe connections) that is used to discharge waste to the ground. Historically the type of UIC wells used in Connecticut were "Class V" (not hazardous wastes). They were typically drywell-type structures, and were most commonly used for automotive service drains. In Connecticut these types of wells are no longer allowed, and groundwater discharges of wastes other than domestic sewage or clean water are not allowed to the ground in existing or potential groundwater drinking supply area. Stormwater structures such as infiltration drywells or trenches, which are susceptible to spills, leaks, or other chemical releases, especially at industrial or petro-chemical commercial sites, may be considered UIC wells.

Care must be taken to ensure that stormwater drywells or infiltration trenches do not threaten groundwater quality, especially drinking water sources. Later chapters in this Manual provide guidance about sites where the use of stormwater infiltration structures should be avoided due to groundwater quality concerns, and sites where they could be used to recharge stormwater with pretreatment or other safeguards.

Public Health Code – Sanitation of Watersheds

Connecticut Public Health Code §19-13-B32i requires that stormwater discharges terminate at least one hundred feet from an established watercourse located within lands tributary to public drinking water supplies, including both surface and groundwater sources. If such termination is not possible, discharges that terminate within 100 feet of a watercourse require review by the Department of Public Health. Discharges within 100 feet must include adequate flow energy dissipation and must not adversely impact stream quality. This requirement applies to surface drinking water supply watershed areas, approximately 16.5 percent of Connecticut's land area, and to streams tributary to public drinking water supply wells.

1.5.3 Local Programs

State-Mandated Programs

Several of the state programs discussed above require the implementation of municipal regulations and permitting processes, including:

Inland Wetlands and Watercourses Act: CGS §22a-42(c) requires that each municipality establish an Inland Wetlands and Watercourses Agency and local regulations regulating private and municipal work located in or affecting wetlands or watercourses. The regulations must conform to model regulations developed by DEP and contain certain criteria and procedures for application review. The application must address measures to prevent or minimize pollution, including those associated with stormwater runoff.

Erosion and Sediment Control Act: The Erosion and Sediment Control Act requires that municipalities adopt regulations requiring that a soil erosion and sediment control plan be submitted with any application for development within the municipality when the disturbed area of such development is more than one-half acre.

Coastal Management Act/Coastal Site Plan Review: Under the CCMA, coastal municipalities are required to implement Connecticut's Coastal Management Program through their existing planning and zoning authorities. Most activities within the coastal boundary, as defined by DEP according to CGS §22a-94, require municipal Coastal Site Plan Review (CSPR). In this review process, the applicant must describe the proposed project and identify coastal resources in the project area and potential

impacts to those resources. Local planning and zoning authorities must decide whether potential adverse impacts to water quality or other coastal resources are acceptable. A description of stormwater management measures may be required depending on the size of a project and the municipality concerned. CGS §22a-101 allows coastal municipalities to develop Municipal Coastal Programs, which are revisions to plans of conservation and development and zoning regulations to focus on the coastal resources and coastal management issues unique to each town.

Municipal Planning/Zoning: Public Act 91-170 (codified in CGS §8-2(b) and CGS §8-35a) and Public Act 91-395 (codified in CGS §8-23(a)) require that the zoning regulations and plans of conservation and development for any municipality contiguous to Long Island Sound, and the regional plans of development of each region contiguous to Long Island Sound, be made with reasonable consideration for the restoration and protection of the ecosystem and habitat of Long Island Sound. These documents must also contain recommendations and practices to reduce hypoxia, pathogens, toxic contaminants, and floatable debris in Long Island Sound.

Aquifer Protection Act: Under the aquifer protection land use regulations, issued in 2004, municipalities containing aquifer protection areas are directed to adopt regulations requiring local permitting for all regulated activities within aquifer protection areas. In addition, regulated activities within an aquifer protection area may require a stormwater management plan to ensure that stormwater runoff generated by the proposed activity is managed in a manner to prevent pollution of ground water.

Municipal Planning/Zoning

Development projects and other activities subject to approval by municipal planning and zoning authorities are typically subject to review for potential impacts to environmental resources. Depending upon the local regulations, stormwater quantity and/or quality may be regulated. In addition, some municipalities have developed or are considering developing local stormwater quality ordinances.

Additional Information Sources

Watershed Management

Center for Watershed Protection. 2000. *The Practice of Watershed Protection*, Ellicott City, Maryland.

Davenport, T.E. 2002. *The Watershed Project Management Guide*. Lewis Publishers/CRC Press.

U.S. Environmental Protection Agency, Office of Water. 2001. *Protecting and Restoring America's Watersheds: Status, Trends, and Initiatives in Watershed Management*. EPA-840-R-00-001.

Agricultural Runoff

Connecticut Department of Environmental Protection and U.S. Department of Agriculture, Natural Resources Conservation Service. 1993. *Guidelines for Protecting Connecticut's Water Resources.*

U.S. Environmental Protection Agency, Office of Water. 1993. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters.*

U.S. Department of Agriculture, Natural Resource Conservation Service. *National Handbook of Conservation Practices.*

Drainage Design and Flood Control

Connecticut Department of Transportation (DOT). 2000. *Connecticut Department of Transportation Drainage Manual.*

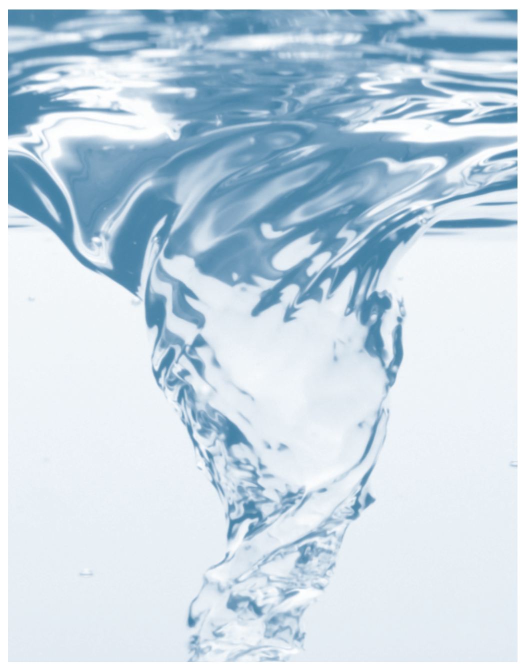
Natural Resource Conservation Service (formerly Soil Conservation Service). 1986. Urban Hydrology for Small Watersheds, TR-55.

Water Environment Federation (WEF) and American Society of Civil Engineers (ASCE). 1992. *Design and Construction of Urban Stormwater Management Systems (Urban Runoff Quality Management (WEF Manual of Practice FD-20 and ASCE Manual and Report on Engineering Practice No. 77).*

Erosion and Sediment Control

Connecticut Council on Soil and Water Conservation and the Connecticut Department of Environmental Protection. 2002. *2002 Connecticut Guidelines for Soil Erosion and Sediment Control, DEP Bulletin 34.*

Chapter 2
Why Stormwater Matters: The Impacts of Urbanization



Volume 1: Background

Chapter 2

Why Stormwater Matters: The Impacts of Urbanization

2.1 What is Urban Stormwater Runoff? 2-2

2.2 Hydrologic Impacts 2-6

2.3 Stream Channel and Floodplain Impacts..2-6

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2.1 What is Urban Stormwater Runoff?

Stormwater runoff is a natural part of the hydrological cycle, which is the distribution and movement of water between the earth's atmosphere, land, and water bodies. Rainfall, snowfall, and other frozen precipitation send water to the earth's surfaces. Stormwater runoff is surface flow from precipitation that accumulates in and flows through natural or man-made conveyance systems during and immediately after a storm event or upon snowmelt. Stormwater runoff eventually travels to surface water bodies as diffuse overland flow, a point discharge, or as groundwater flow. Water that seeps into the ground eventually replenishes groundwater aquifers and surface waters such as lakes, streams, and the oceans. Groundwater recharge also helps maintain water flow in streams and wetland moisture levels during dry weather. Water is returned to the atmosphere through evaporation and transpiration to complete the cycle. A schematic of the hydrologic cycle is shown in **Figure 2-1**.

Traditional development of the landscape with impervious surfaces such as buildings, roads, and parking lots, as well as storm sewer systems and other man-made features, alters the hydrology of a watershed and has the potential to adversely affect water quality and aquatic habitat. As a result of development, vegetated and forested land that consists of pervious surfaces is largely replaced by land uses with impervious surfaces. This transformation increases the amount of stormwater runoff from a site, decreases infiltration and groundwater recharge, and alters natural drainage patterns. This effect is shown schematically in **Figure 2-2.** In addition, natural pollutant removal mechanisms provided by on-site vegetation and soils have less opportunity to remove pollutants from stormwater runoff in developed areas. During construction, soils are exposed to rainfall, which increases the potential for erosion and sedimentation. Development can also introduce new sources of pollutants from everyday activities associated with residential, commercial, and industrial land uses. The development process is known as "urbanization." Stormwater runoff from developed areas is commonly referred to as "urban stormwater runoff."

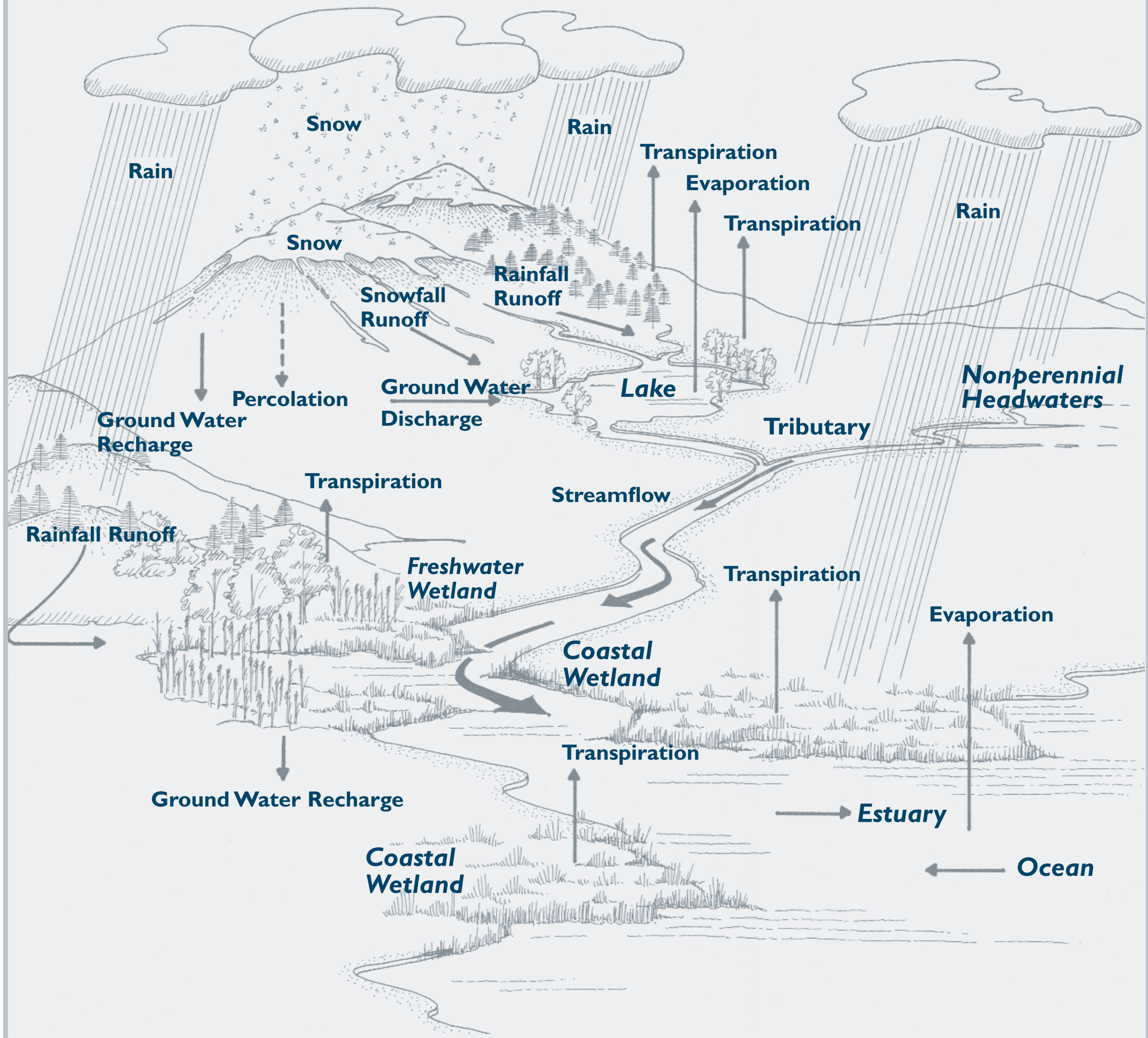
Urban stormwater runoff can be considered both a point source and a nonpoint source of pollution. Stormwater runoff that flows into a conveyance system and is discharged through a pipe, ditch, channel, or other structure is considered a point source discharge under EPA's National Pollutant Discharge Elimination System (NPDES) permit program, as administered by DEP. Stormwater runoff that flows over the land surface and is not concentrated in a defined channel is considered nonpoint source pollution. In most cases stormwater runoff begins as a nonpoint source and becomes a point source discharge (MADEP, 1997). Both point and nonpoint sources of urban stormwater runoff have been shown to be significant causes of water quality impairment (EPA, 2000).

According to the draft 2004 Connecticut list of impaired waters ("303(d)") list prepared pursuant to Section 303(d) of the Federal Clean Water Act), urban runoff and stormwater discharges were a significant cause of aquatic life and contact recreation (e.g. swimming and boating) impairment to approximately one-quarter of the state's 893 miles of major rivers and streams. Urban runoff is also reported as a contributor to excessive nutrient enrichment in numerous lakes and ponds throughout the state, as well as a continued threat to estuarine waters and Long Island Sound (EPA, 2001). **Table 2-1** summarizes impaired Connecticut water bodies (i.e., those not meeting water quality standards) for which urban runoff, stormwater discharges, or other wet-weather sources are suspected causes of impairment (DEP, 2004 draft). This list does not include water bodies impaired as a result of other related causes such as combined sewer overflows (CSOs) and agricultural runoff or unknown sources.

Impervious cover has emerged as a measurable, integrating concept used to describe the overall health of a watershed. Numerous studies have documented the cumulative effects of urbanization on stream and watershed ecology (See, e.g., Schueler et al., 1992; Schueler, 1994; Schueler, 1995; Booth and Reinelt, 1993, Arnold and Gibbons, 1996; Brant, 1999; Shaver and Maxted, 1996). Research has shown that when impervious cover in a watershed reaches between 10 and 25 percent, ecological stress becomes clearly apparent. Beyond 25 percent, stream stability is reduced, habitat is lost, water quality becomes degraded, and biological diversity decreases (NRDC, May 1999). **Figure 2-3** illustrates this effect.

To put these thresholds into perspective, typical total imperviousness in medium density, single-family home residential areas ranges from 25 to nearly 60 percent (Schueler, 1995). **Table 2-2** indicates typical percentages of impervious cover for various land uses in Connecticut and the Northeast

Figure 2-1 Hydrologic Cycle



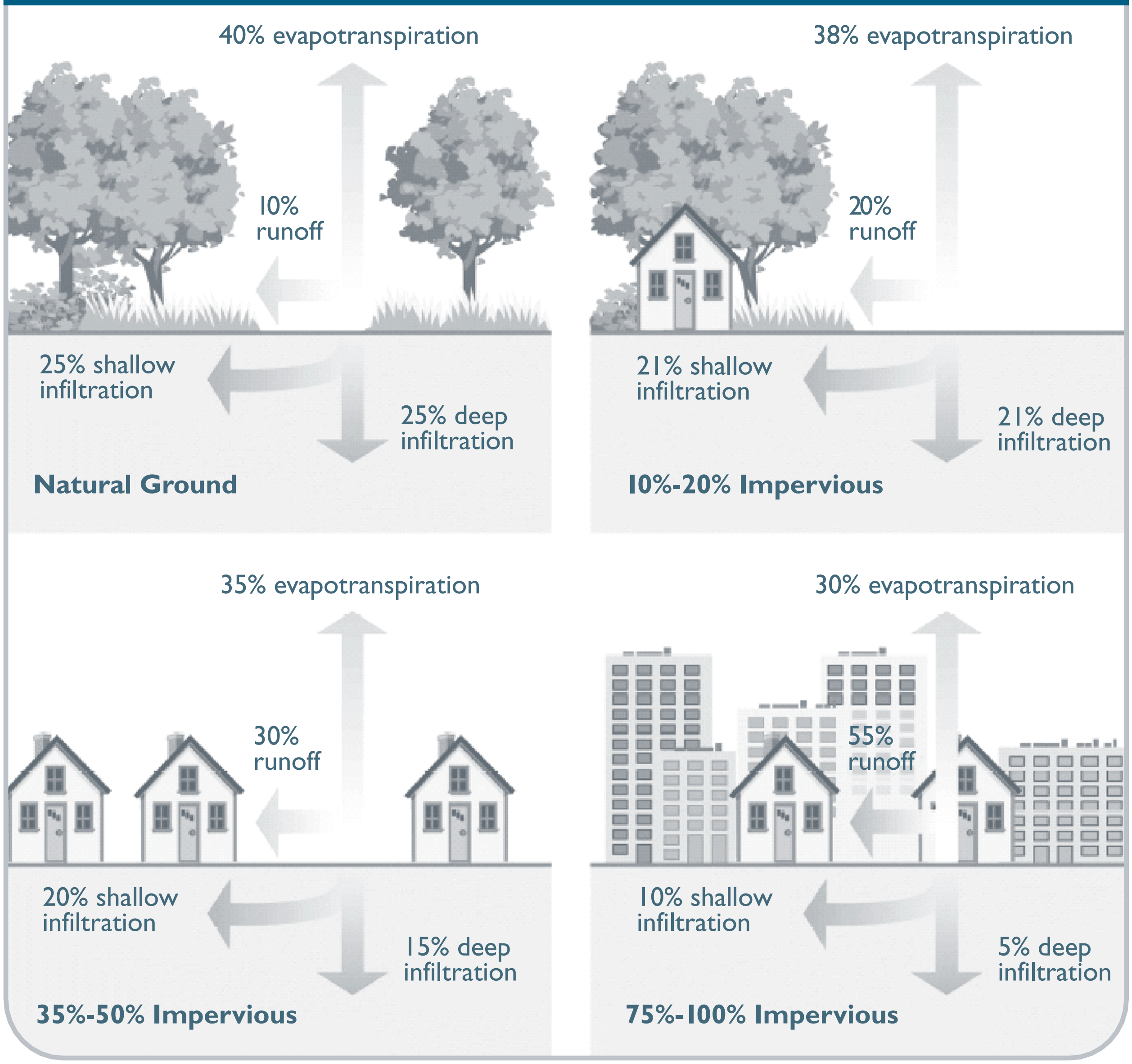
Source: National Water Quality Inventory, U.S. EPA, 1998.

Table 2-1 Connecticut Water Bodies Impaired by Urban Stormwater Runoff

Major Basin	Water Body	Major Basin	Water Body
Pawcatuck River Basin	Pawcatuck River Estuary	Thames River Basin	Thames River Estuary Eagleville Brook Quinebaug River
Southeast Coastal Basins	Fenger Brook Stonington Harbor West and Palmer Coves Mumford Cove Alewife Cove Long Island Sound East Niantic Bay: upper bay, river and offshore Wequetequock Cove Copps Brook Estuary/Quiambog Cove Mystic River Estuary Pequonock River Estuary/Baker Cove Jordan Cove Pattagansett River Estuary Fourmile River	Housatonic River Basin	Housatonic River Housatonic River Estuary Hitchcock Lake Ball Pond Still River Kenosia Lake Padanaram Brook Sympaug Brook Naugatuck River Naugatuck River, West Branch Steele Brook Mad River Hop Brook Lake
Southwest Coastal Basins	Bridgeport Harbor Blackrock Harbor Sherwood Mill Pond/Compo Cove Westcott Cove Greenwich Cove Byram Beach Captain Harbor Rooster River Ash Creek Upper/Lower Mill Ponds Sasco Brook/Estuary Saugatuck River Estuary Norwalk River and Harbor Ridgefield Brook Five Mile River/Estuary Darien Cove Holly Pond/Cove Harbor Stamford Harbor Cos Cob Harbor Byram River/Estuary Long Island Sound West: Southport Harbor	South Central Coastal Basins	Oyster River Tributary Madison Beaches Island Bay/Joshua Cove Thimble Islands Plum Bank Indiantown Harbor Patchogue River Clinton Harbor Guilford Harbor Cedar Pond Linsley Pond Branford Harbor Hanover Pond Quinnipiac River New Haven Harbor Tenmile River Sodom Brook Harbor Brook Wharton Brook Mill River Edgewood Park Pond West River Milford Harbor/Gulf Pond Long Island sound Central Menunnketesuck River Hammonasset River Indian River Hammock Riber Branford Supply Pond West Pisgah River Pine Gutter Brook Allen Brook
Connecticut River Basin	Pequabuck River Birge Pond Pine Lake Park River, South Branch Batterson Park Pond Piper Brook Trout Brook Park River, North Branch Hockanum River Union Pond Mattabesset River Willow Brook Pocotopaug Creek Connecticut River Estuary	Crystal Lake John Hall Brook Little Brook Spruce Brook Coles Brook Miner Brook Belcher Brook Webster Brook Sawmill Brook	

Source: 2004 List of Connecticut Waterbodies Not Meeting Water Quality Standards (draft 5/14/02). The impaired waters list is updated by DEP every two to three years.

Figure 2-2 Impacts of Urbanization on the Hydrologic Cycle



Source: Federal Interagency SRWG, 2000.

United States. It is important to note that these tabulated values reflect impervious coverage within individual land uses, but do not reflect overall watershed imperviousness, for which the ecological stress thresholds apply. However, in developed watersheds with significant residential, commercial, and industrial development, overall watershed imperviousness often exceeds the ecological stress thresholds.

Table 2-2
Typical Impervious Coverage of Land Uses in the Northeast U.S.

Land Use	% Impervious Cover
Commercial and Business District	85-100
Industrial	70-80
High Density Residential	45-60
Medium Density Residential	35-45
Low Density Residential	20-40
Open Areas	0-10

Source: MADEP, 1997; Kauffman and Brant, 2000; Arnold and Gibbons, 1996; Soil Conservation Service, 1975.

The impacts of development on stream ecology can be grouped into four categories:

1. Hydrologic Impacts
2. Stream Channel and Floodplain Impacts
3. Water Quality Impacts
4. Habitat and Ecological Impacts

The extent of these impacts is a function of climate, level of imperviousness, and change in land use in a watershed (WEF and ASCE, 1998). Each of these impacts is described further in the following sections.

2.2 Hydrologic Impacts

Development can dramatically alter the hydrologic regime of a site or watershed as a result of increases in impervious surfaces. The impacts of development on hydrology may include:

- *Increased runoff volume*
- *Increased peak discharges*
- *Decreased runoff travel time*
- *Reduced groundwater recharge*
- *Reduced stream baseflow*
- *Increased frequency of bankfull and overbank floods*
- *Increased flow velocity during storms*
- *Increased frequency and duration of high stream flow*

Figure 2-4 depicts typical pre-development and post-development streamflow hydrographs for a developed watershed.

2.3 Stream Channel and Floodplain Impacts

Stream channels in urban areas respond to and adjust to the altered hydrologic regime that accompanies urbanization. The severity and extent of stream adjustment is a function of the degree of watershed imperviousness (WEF and ASCE, 1998). The impacts of development on stream channels and floodplains may include:

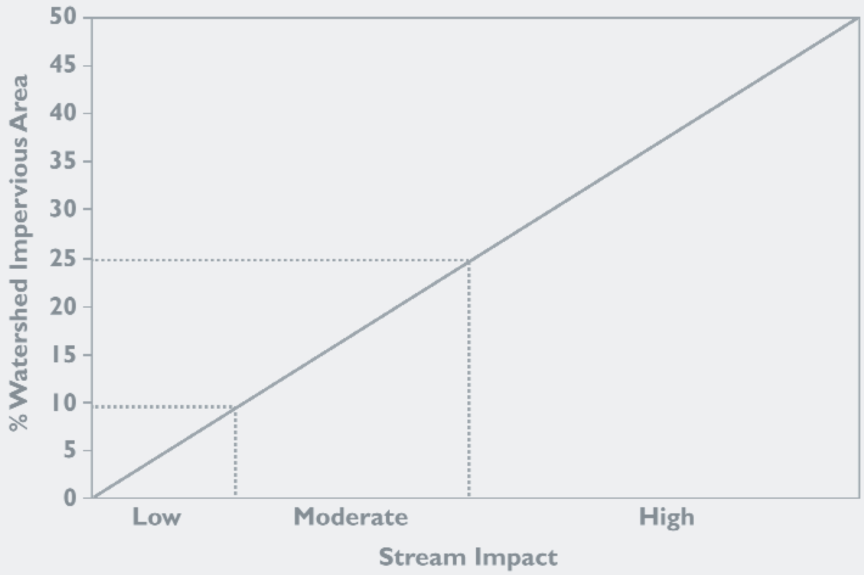
- *Channel scour, widening, and downcutting*
- *Streambank erosion and increased sediment loads*
- *Shifting bars of coarse sediment*
- *Burying of stream substrate*
- *Loss of pool/riffle structure and sequence*
- *Man-made stream enclosure or channelization*
- *Floodplain expansion*

2.4 Water Quality Impacts

Urbanization increases the discharge of pollutants in stormwater runoff. Development introduces new sources of stormwater pollutants and provides impervious surfaces that accumulate pollutants between storms. Structural stormwater collection and conveyance systems allow stormwater pollutants to quickly wash off during storm or snowmelt events and discharge to downstream receiving waters. By contrast, in undeveloped areas, natural processes such as infiltration, interception, depression storage, filtration by vegetation, and evaporation can reduce the quantity of stormwater runoff and remove pollutants. Impervious areas decrease the natural stormwater purification functions of watersheds and increase the potential for water quality impacts in receiving waters.

Urban land uses and activities can also degrade groundwater quality if stormwater with high pollutant loads is directed into the soil without adequate treatment. Certain land uses and activities, sometimes referred to as stormwater "hotspots" (e.g., commercial parking lots, vehicle service and maintenance facilities,

Figure 2-3
Relationship Between Watershed Imperviousness and Stream Health



Source: Adapted from Schueler, 1992 and Prince George's County, Maryland, 1999.

and industrial rooftops), are known to produce higher loads of pollutants such as metals and toxic chemicals. Soluble pollutants can migrate into groundwater and potentially contaminate wells in groundwater supply aquifer areas.

Table 2-3 lists the principal pollutants found in urban stormwater runoff, typical pollutant sources, related impacts to receiving waters, and factors that promote pollutant removal. **Table 2-3** also identifies those pollutants that commonly occur in a dissolved or soluble form, which has important implications for the selection and design of stormwater management practices described later in this manual. Chapter Three contains additional information on pollutant removal mechanisms for various stormwater pollutants.

Excess Nutrients

Urban stormwater runoff typically contains elevated concentrations of nitrogen and phosphorus that are most commonly derived from lawn fertilizer, detergents, animal waste, atmospheric deposition, organic matter, and improperly installed or failing septic systems. Nutrient concentrations in urban runoff are similar to those found in secondary wastewater effluents (American Public Works Association and Texas Natural Resource Conservation Commission). Elevated nutrient concentrations in stormwater runoff can result in excessive growth of vegetation or algae in streams, lakes, reservoirs, and estuaries, a process known as accelerated eutrophication. Phosphorus is typically the growth-limiting nutrient in freshwater systems, while nitrogen is growth-limiting in estuarine and marine systems. This means that in marine waters algal growth usually responds to the level of nitrogen in the water, and in fresh waters algal growth is usually stimulated by the level of available or soluble phosphorus (DEP, 1995).

Nutrients are a major source of degradation in many of Connecticut's water bodies. Excessive nitrogen loadings have led to hypoxia, a condition of low dissolved oxygen, in Long Island Sound. A Total Maximum Daily Load (TMDL) for nitrogen has been developed for Long Island Sound, which will restrict nitrogen loadings from point and non-point sources throughout Connecticut. Phosphorus in runoff has impacted the quality of many of Connecticut's lakes and ponds, which are susceptible to eutrophication from phosphorus loadings. Nutrients are also detrimental to submerged aquatic vegetation (SAV). Nutrient enrichment can favor the growth of epiphytes (small plants that grow attached to other things, such as blades of eelgrass) and increase amounts of phytoplankton and zooplankton in the water column, thereby decreasing available light. Excess nutrients can also favor the growth of macroalgae, which can dominate and displace eelgrass beds and dramatically change the food web (Deegan et al., 2002).

Table 2-3 Summary of Urban Stormwater Pollutants

Stormwater Pollutant	Potential Sources	Receiving Water Impacts	Removal Promoted by[1]
Stormwater Pollutant Excess Nutrients Nitrogen, Phosphorus (soluble)	Animal waste, fertilizers, failing septic systems, landfills, atmospheric deposition, erosion and sedimentation, illicit sanitary connections	Algal growth, nuisance plants, ammonia toxicity, reduced clarity, oxygen deficit (hypoxia), pollutant recycling from sediments, decrease in submerged aquatic vegetation (SAV)	Phosphorus: High soil exchangeable aluminum and/or iron content, vegetation and aquatic plants Nitrogen: Alternating aerobic and anaerobic conditions, low levels of toxicants, near neutral pH (7)
Sediments Suspended, Dissolved, Deposited, Sorbed Pollutants	Construction sites, streambank erosion, washoff from impervious surfaces	Increased turbidity, lower dissolved oxygen, deposition of sediments, aquatic habitat alteration, sediment and benthic toxicity	Low turbulence, increased residence time
Pathogens Bacteria, Viruses	Animal waste, failing septic systems, illicit sanitary connections	Human health risk via drinking water supplies, contaminated swimming beaches, and contaminated shellfish consumption	High light (ultraviolet radiation), increased residence time, media/soil filtration, disinfection
Organic Materials Biochemical Oxygen Demand, Chemical Oxygen Demand	Leaves, grass clippings, brush, failing septic systems	Lower dissolved oxygen, odors, fish kills, algal growth, reduced clarity	Aerobic conditions, high light, high soil organic content, low levels of toxicants, near neutral pH (7)
Hydrocarbons Oil and Grease	Industrial processes; commercial processes; automobile wear, emissions, and fluid leaks; improper oil disposal	Toxicity of water column and sediments, bioaccumulation in food chain organisms	Low turbulence, increased residence time, physical separation or capture techniques
Metals Copper, Lead, Zinc, Mercury, Chromium, Aluminum (soluble)	Industrial processes, normal wear of automobile brake linings and tires, automobile emissions and fluid leaks, metal roofs	Toxicity of water column and sediments, bioaccumulation in food chain organisms	High soil organic content, high soil cation exchange capacity, near neutral pH (7)
Synthetic Organic Chemicals Pesticides, VOCs, SVOCs, PCBs, PAHs (soluble)	Residential, commercial, and industrial application of herbicides, insecticides, fungicides, rodenticides; industrial processes; commercial processes	Toxicity of water column and sediments, bioaccumulation in food chain organisms	Aerobic conditions, high light, high soil organic content, low levels of toxicants, near neutral pH (7), high temperature and air movement for volatilization of VOCs
Deicing Constituents Sodium, Calcium, Potassium Chloride Ethylene Glycol Other Pollutants (soluble)	Road salting and uncovered salt storage. Snowmelt runoff from snow piles in parking lots and roads during the spring snowmelt season or during winter rain on snow events.	Toxicity of water column and sediments, contamination of drinking water, harmful to salt intolerant plants. Concentrated loadings of other pollutants as a result of snowmelt.	Aerobic conditions, high light, high soil organic content, low levels of toxicants, near neutral pH (7)
Trash and Debris	Litter washed through storm drain network	Degradation of aesthetics, threat to wildlife, potential clogging of storm drainage system	Low turbulence, physical straining/capture
Freshwater Impacts	Stormwater discharges to tidal wetlands and estuarine environments	Dilution of the high marsh salinity and encouragement of the invasion of brackish or upland wetland species such as Phragmites	Stormwater retention and volume reduction
Thermal Impacts	Runoff with elevated temperatures from contact with impervious surfaces (asphalt)	Adverse impacts to aquatic organisms that require cold and cool water conditions	Use of wetland plants and trees for shading, increased pool depths

Source: Adapted from DEP, 1995; Metropolitan Council, 2001; Watershed Management Institute, Inc., 1997.

1 Factors that promote removal of most stormwater pollutants include:

- Increasing hydraulic residence time
- Low turbulence
- Fine, dense, herbaceous plants
- Medium-fine textured soil

Sediments

Sediment loading to water bodies occurs from washoff of particles that are deposited on impervious surfaces such as roads and parking lots, soil erosion associated with construction activities, and streambank erosion. Although some erosion and sedimentation is natural, excessive sediment loads can be detrimental to aquatic life including phytoplankton, algae, benthic invertebrates, and fish, by interfering with photosynthesis, respiration, growth, and reproduction. Solids can either remain in suspension or settle to the bottom of the water body. Suspended solids can make the water cloudy or turbid, detract from the aesthetic and recreational value of a water body, and harm SAV, finfish, and shellfish. Sediment transported in stormwater runoff can be deposited in a stream or other water body or wetland and can adversely impact fish and wildlife habitat by smothering bottom dwelling aquatic life and changing the bottom substrate. Sediment deposition in water bodies can result in the loss of deep-water habitat and can affect navigation, often necessitating dredging. Sediment transported in stormwater runoff can also carry other pollutants such as nutrients, metals, pathogens, and hydrocarbons.

Pathogens

Pathogens are bacteria, protozoa, and viruses that can cause disease in humans. The presence of bacteria such as fecal coliform or enterococci is used as an indicator of pathogens and of potential risk to human health (DEP, 1995). Pathogen concentrations in urban runoff routinely exceed public health standards for water contact recreation and shellfishing. Sources of pathogens in stormwater runoff include animal waste from pets, wildlife, and waterfowl; combined sewers; failing septic systems; and illegal sanitary sewer cross-connections. High levels of indicator bacteria in stormwater have commonly led to the closure of beaches and shellfishing beds along coastal areas of Connecticut.

Organic Materials

Oxygen-demanding organic substances such as grass clippings, leaves, animal waste, and street litter are commonly found in stormwater. The decomposition of such substances in water bodies can deplete oxygen from the water, thereby causing similar effects to those caused by nutrient loading. Organic matter is of primary concern in water bodies where oxygen is not easily replenished, such as slower moving streams, lakes, and estuaries. An additional concern for unfiltered water supplies is the formation of trihalomethane (THM), a carcinogenic disinfection byproduct generated by the mixing of chlorine with water high in organic carbon (NYDEC, 2001).

Hydrocarbons

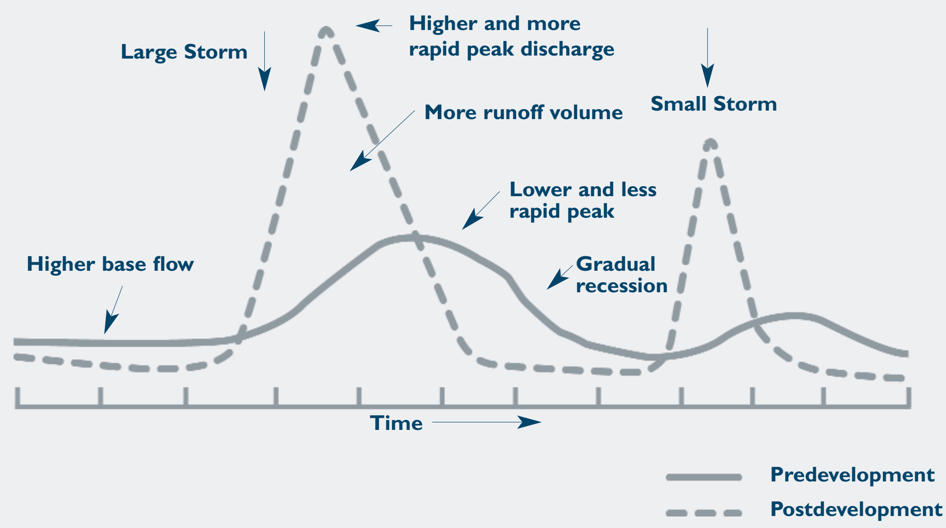
Urban stormwater runoff contains a wide array of hydrocarbon compounds, some of which are toxic to aquatic organisms at low concentrations (Woodward-Clyde, 1990). The primary sources of hydrocarbons in urban runoff are automotive. Source areas with higher concentrations of hydrocarbons in stormwater runoff include roads, parking lots, gas stations, vehicle service stations, residential parking areas, and bulk petroleum storage facilities.

Metals

Metals such as copper, lead, zinc, mercury, and cadmium are commonly found in urban stormwater runoff. Chromium and nickel are also frequently present (USEPA, 1983). The primary sources of these metals in stormwater runoff are vehicular exhaust residue, fossil fuel combustion, corrosion of galvanized and chrome-plated products, roof runoff, stormwater runoff from industrial sites, and the application of deicing agents. Architectural copper associated with building roofs, flashing, gutters, and downspouts has been shown to be a source of copper in stormwater runoff in Connecticut and other areas of the country (Barron, 2000; Tobiason, 2001). Marinas have also been identified as a source of copper and aquatic toxicity to inland and marine waters (Sailer Environmental, Inc. 2000). Washing or sandblasting of boat hulls to remove salt and barnacles also removes some of the bottom paint, which contains copper and zinc additives to protect hulls from deterioration.

In Connecticut, discharge of metals to surface waters is of particular concern. Metals can be toxic to aquatic organisms, can bioaccumulate, and have the potential to contaminate drinking water supplies. Many major rivers in Connecticut have copper levels that exceed Connecticut's Copper Water Quality Criteria. Although metals generally attach themselves to the solids in stormwater runoff or receiving waters, recent studies have demonstrated that dissolved metals, particularly copper and zinc, are the primary toxicants in stormwater runoff from industrial facilities throughout Connecticut (Mas et al., 2001; New England Bioassay, Inc., 2001). Additionally, stormwater runoff can contribute to elevated metals in aquatic sediments. The metals can become bioavailable where the bottom sediment is anaerobic (without oxygen) such as in a lake or estuary. Metal accumulation in sediments has resulted in impaired aquatic habitat and more difficult maintenance dredging operations in estuaries because of the special handling requirements for contaminated sediments.

Figure 2-4 Changes in Stream Hydrology as a Result of Urbanization



Source: Schueler, 1992, in Metropolitan Council, 2001.

Synthetic Organic Chemicals

Synthetic organic chemicals can also be present at low concentrations in urban stormwater. Pesticides, phenols, polychlorinated biphenyls (PCBs), and polynuclear or polycyclic aromatic hydrocarbons (PAHs) are the compounds most frequently found in stormwater runoff. Such chemicals can exert varying degrees of toxicity on aquatic organisms and can bioaccumulate in fish and shellfish. Toxic organic pollutants are most commonly found in stormwater runoff from industrial areas. Pesticides are commonly found in runoff from urban lawns and rights-of-way (NYDEC, 2001). A review of monitoring data on stormwater runoff quality from industrial facilities has shown that PAHs are the most common organic toxicants found in roof runoff, parking area runoff, and vehicle service area runoff (Pitt et al., 1995).

Deicing Constituents

Salting of roads, parking lots, driveways, and sidewalks during winter months and snowmelt during the early spring result in the discharge of sodium, chloride, and other deicing compounds to surface waters via stormwater runoff. Excessive amounts of sodium and chloride may have harmful effects on water, soil and vegetation, and can also accelerate corrosion of metal surfaces. Drinking water supplies, particularly groundwater wells, may be contaminated by runoff from roadways where deicing compounds have been applied or from highway facilities where salt mixes are improperly stored. In addition, sufficient concentrations of chlorides may prove toxic to certain aquatic species. Excess sodium in drinking water can lead to health problems in infants ("blue baby syndrome") and individuals on low sodium diets. Other deicing compounds may contain nitrogen, phosphorus, and oxygen demanding substances. Antifreeze from automobiles is a source of phosphates, chromium, copper, nickel, and cadmium.

Other pollutants such as sediment, nutrients, and hydrocarbons are released from the snowpack during the spring snowmelt season and during winter rain-on-snow events. The pollutant loading during snowmelt can be significant and can vary considerably during the course of the melt event (NYDEC, 2001). For example, a majority of the hydrocarbon load from snowmelt occurs during the last 10 percent of the event and towards the end of the snowmelt season (Oberts, 1994). Similarly, PAHs, which are hydrophobic materials, remain in the snowpack until the end of the snowmelt season, resulting in highly concentrated loadings (Metropolitan Council, 2001).

Trash and Debris

Trash and debris are washed off of the land surface by stormwater runoff and can accumulate in storm drainage systems and receiving waters. Litter detracts from the aesthetic value of water bodies and can harm aquatic life either directly (by being mistaken for food) or indirectly (by habitat modification). Sources of trash and debris in urban stormwater runoff include residential yard waste, commercial parking lots, street refuse, combined sewers, illegal dumping, and industrial refuse.

Freshwater Impacts

Discharge of freshwater, including stormwater, into brackish and tidal wetlands can alter the salinity and hydroperiod of these environments, which can encourage the invasion of brackish or freshwater wetland species such as Phragmites.

Thermal Impacts

Impervious surfaces may increase temperatures of stormwater runoff and receiving waters. Roads and other impervious surfaces heated by sunlight may transport thermal energy to a stream during storm events. Direct exposure of sunlight to shallow ponds and impoundments as well as unshaded streams may further elevate water temperatures. Elevated water temperatures can exceed fish and invertebrate tolerance limits, reducing survival and lowering resistance to disease. Coldwater fish such as trout may be eliminated, or the habitat may become marginally supportive of coldwater species. Elevated water temperatures also contribute to decreased oxygen levels in water bodies and dissolution of solutes.

Concentrations of pollutants in stormwater runoff vary considerably between sites and storm events. Typical average pollutant concentrations in urban stormwater runoff in the Northeast United States are summarized in **Table 2-4.**

Table 2-4
Average Pollutant Concentrations in Urban Stormwater Runoff

Constituent	Units	Concentration
Total Suspended Solids[1]	mg/l	54.5
Total Phosphorus[1]	mg/l	0.26
Soluble Phosphorus[1]	mg/l	0.10
Total Nitrogen[1]	mg/l	2.00
Total Kjeldahl Nitrogen[1]	mg/l	1.47
Nitrite and Nitrate[1]	mg/l	0.53
Copper[1]	μg/l	11.1
Lead[1]	μg/l	50.7
Zinc[1]	μg/l	129
BOD[1]	mg/l	11.5
COD[1]	mg/l	44.7
Organic Carbon[2]	mg/l	11.9
PAH[3]	mg/l	3.5
Oil and Grease[4]	mg/l	3.0
Fecal Coliform[5]	Colonies/100 ml	15,000
Fecal Strep[5]	Colonies/100 ml	35,400
Chloride (snowmelt)[6]	mg/l	116

Source: Adapted from NYDEC, 2001; original sources are listed below.
[1]Pooled Nationwide Urban Runoff Program/USGS (Smullen and Cave, 1998)
[2]Derived from National Pollutant Removal Database (Winer, 2000)
[3]Rabanal and Grizzard, 1996
[4]Crunkilton et al., 1996
[5]Schueler, 1999
[6]Oberts, 1994
mg/l = milligrams per liter
μg/l= micrograms per liter

2.5 Habitat and Ecological Impacts

Changes in hydrology, stream morphology, and water quality that accompany the development process can also impact stream habitat and ecology. A large body of research has demonstrated the relationship between urbanization and impacts to aquatic habitat and organisms (**Table 2-5**). Habitat and ecological impacts may include:

- *A shift from external (leaf matter) to internal (algal organic matter) stream production*
- *Reduction in the diversity, richness, and abundance of the stream community (aquatic insects, fish, amphibians)*
- *Destruction of freshwater wetlands, riparian buffers, and springs*
- *Creation of barriers to fish migration*

2.6 Impacts on Other Receiving Environments

The majority of research on the ecological impacts of urbanization has focused on streams. However, urban stormwater runoff has also been shown to adversely impact other receiving environments such as wetlands, lakes, and estuaries. Development alters the physical, geochemical, and biological characteristics of wetland systems. Lakes, ponds, wetlands, and SAV are impacted through deposition of sediment and particulate pollutant loads, as well as accelerated eutrophication caused by increases in nutrient loadings. Estuaries experience increased sedimentation and pollutant loads, and more extreme salinity swings caused by increased runoff and reduced baseflow. **Table 2-5** summarizes the effects of urbanization on these receiving environments.

Table 2-5 Effects of Urbanization on Other Receiving Environments

Receiving Environment	Impacts
Wetlands	❍ Changes in hydrology and hydrogeology ❍ Increased nutrient and other contaminant loads ❍ Compaction and destruction of wetland soil ❍ Changes in wetland vegetation ❍ Changes in or loss of habitat ❍ Changes in the community (diversity, richness, and abundance) of organisms ❍ Loss of particular biota ❍ Permanent loss of wetlands
Lakes and Ponds	❍ Impacts to biota on the lake bottom due to sedimentation ❍ Contamination of lake sediments ❍ Water column turbidity ❍ Aesthetic impairment due to floatables and trash ❍ Increased algal blooms and depleted oxygen levels due to nutrient enrichment, resulting in an aquatic environment with decreased diversity ❍ Contaminated drinking water supplies
Estuaries	❍ Sedimentation in estuarial streams and SAV beds ❍ Altered hydroperiod of brackish and tidal wetlands, which results from larger, more frequent pulses of fresh water and longer exposure to saline waters because of reduced baseflow ❍ Hypoxia ❍ Turbidity ❍ Bio-accumulation ❍ Loss of SAV due to nutrient enrichment ❍ Scour of tidal wetlands and SAV ❍ Short-term salinity swings in small estuaries caused by the increased volume of runoff which can impact key reproduction areas for aquatic organisms

Source: Adapted from WEF and ASCE, 1998.

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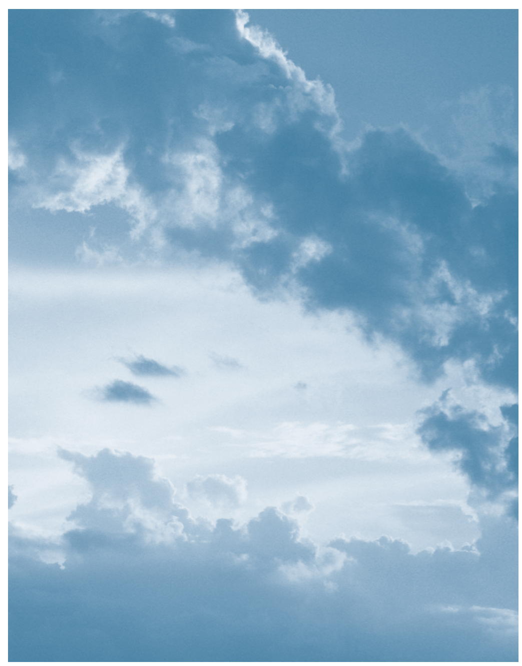
Chapter 3
Preventing and Mitigating Stormwater Impacts



Chapter 3

Preventing and Mitigating Stormwater Impacts

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Effective site planning and design is the most critical and potentially beneficial element of a successful stormwater management program since it addresses the root causes of both stormwater quality and quantity problems early in the development process. Source controls and pollution prevention, as well as construction erosion and sedimentation controls, are also key elements for preventing or mitigating stormwater quality problems. These preventive measures can reduce the size and scope of stormwater treatment and flood control facilities. However, it is also recognized that stormwater treatment and flood control measures are often effective and necessary to achieve water quality and quantity control objectives. **Figure 3-1** shows the relationship and recommended hierarchy of these stormwater management elements.

3.1 Introduction

Stormwater management involves the selective use of various management measures to cost-effectively address the adverse water quality and quantity impacts of urban stormwater runoff described in Chapter Two. **Table 3-1** lists the major elements and associated objectives of a comprehensive stormwater management strategy.

Table 3-1 Elements of a Comprehensive Stormwater Management Strategy

Element	Addresses Water Quality or Quantity?
Effective site planning and design	Quality and quantity
Source control practices and pollution prevention	Quality
Construction erosion and sedimentation controls	Quality
Stormwater treatment practices	Quality (primary), quantity (secondary)
Drainage design and flood control	Quantity (primary), quality (secondary)

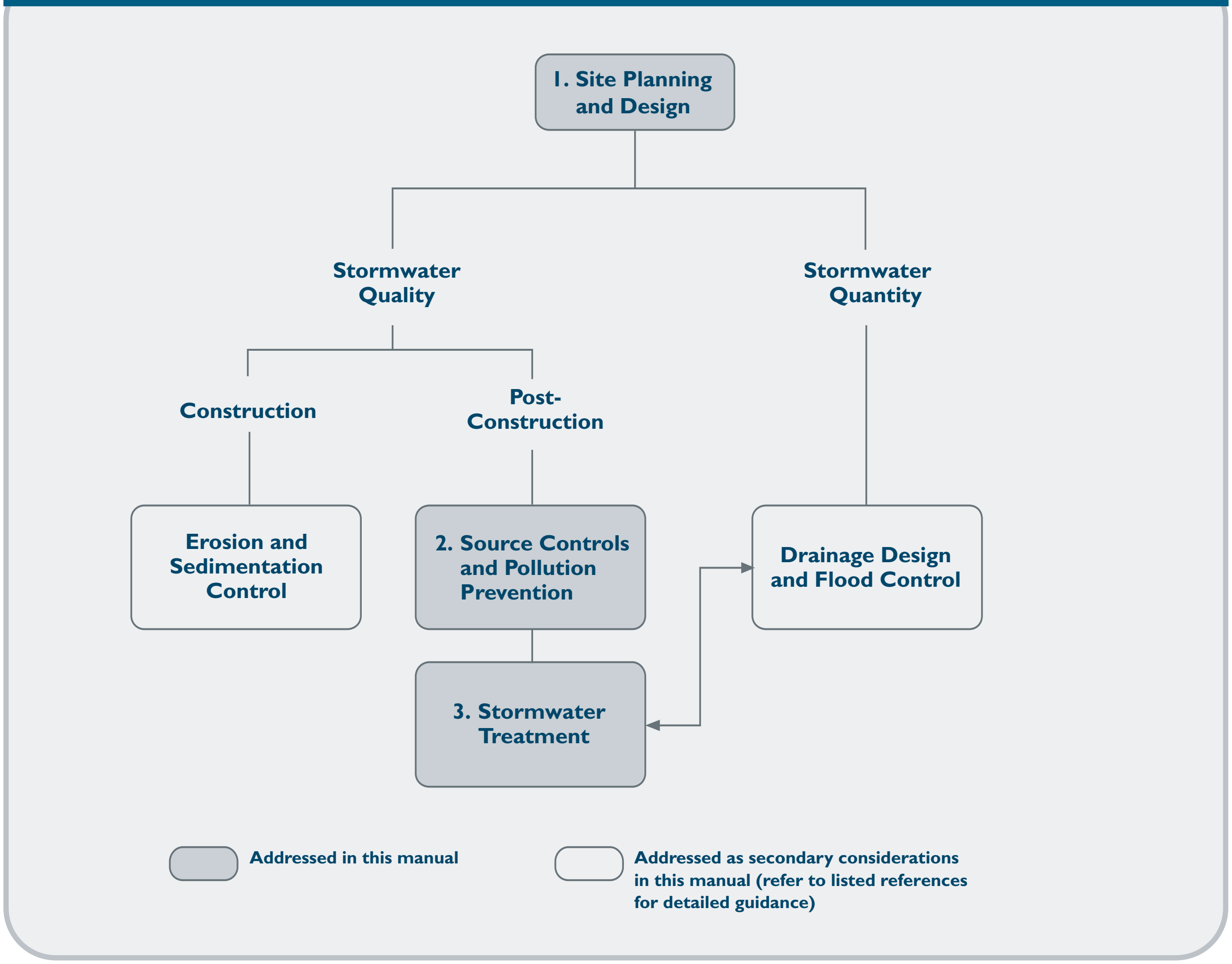
This manual primarily addresses water quality controls through site planning and design, source controls and pollution prevention, and stormwater treatment practices, which are highlighted in **Figure 3-1.** Construction erosion and sediment control, and stormwater quantity control (i.e., flood control and drainage design), are addressed as secondary topics as they relate to water quality. For instance, source controls and stormwater treatment practices can also provide peak runoff attenuation and flood control benefits. Other guidance documents, as well as local ordinances and requirements, are recommended sources of information on these topics, as discussed later in this chapter.

3.2 Guiding Stormwater Management Principles

A comprehensive stormwater management strategy should prevent or mitigate urban runoff problems and protect beneficial uses of receiving waters in a cost-effective manner. The stormwater management measures described in this manual are designed to accomplish this objective by adhering to the following guiding principles:

- *Preserve pre-development site hydrology (i.e., runoff, infiltration, interception, evapotranspiration, groundwater recharge, and stream baseflow) to the extent possible*
- *After construction has been completed and the site is permanently stabilized, reduce the average annual total suspended solids loadings by 80 percent. For high quality receiving waters and sites with the highest potential for significant pollutant loadings, reduce post-development pollutant loadings so that average annual post-development loadings do not exceed pre-development loadings (i.e., no net increase)*

Figure 3-1 Relationship of Stormwater Management Elements



- *Preserve and protect wetlands, stream buffers, natural drainage systems and other natural features that provide water quality and quantity benefits*
- *Manage runoff velocity and volume in a manner that maintains or improves the physical and biological character of existing drainage systems and prevents increases in downstream flooding/streambank erosion*
- *Prevent pollutants from entering receiving waters and wetlands in amounts that exceed the systems' natural ability to assimilate the pollutants and provide the desired functions*
- *Seek multi-objective benefits (i.e., flood control, water quality, recreation, aesthetics, habitat) from stormwater control measures*

3.3 Site Planning and Design

Effective site planning and design (Chapter Four) consists of preventive measures that address the root causes of stormwater problems by maintaining predevelopment hydrologic functions and pollutant removal mechanisms to the extent practical. Site planning that integrates comprehensive stormwater management from the outset is the most effective way to address the adverse water quality and quantity impacts of stormwater runoff from new development and redevelopment projects. Often these site design techniques can reduce or eliminate the need for costly peak flow attenuation and stormwater treatment. This manual emphasizes the use of effective site planning and design techniques early on in the site development process to achieve the greatest stormwater quantity and quality benefits. Site planning and design practices described in this manual include:

- *Alternative site design for streets and parking lots and lot development*

- *Low Impact Development (LID) management practices*
- *Watershed planning*

3.4 Source Control Practices and Pollution Prevention

Source control practices and pollution prevention (Chapter Five) are operational practices that can reduce the types and concentrations of pollutants in stormwater runoff by limiting the generation of pollutants at their source. The guiding principle behind these techniques is to minimize contact of stormwater with potential pollutants, thereby reducing pollutant loads and the size and cost of stormwater treatment. This manual emphasizes the use of source control practices and pollution prevention, in conjunction with effective site planning and design, to reduce the need for and scope of stormwater treatment. Source control practices commonly implemented at residential, commercial, and industrial sites are discussed in this manual, including:

- *Street and Parking Lot Sweeping*
- *Roadway Deicing/Salt Storage*
- *Storm Drainage System Maintenance*
- *Other Road, Highway, and Bridge Maintenance*
- *Illicit Discharge Detection and Elimination*
- *Commercial and Industrial Pollution Prevention Plans*
- *Animal Waste Management*
- *Lawn Care and Landscaping Practices*
- *Model Stormwater Ordinances*
- *Public Education*

3.5 Construction Erosion and Sedimentation Control

As described in Chapter One, soil erosion and sedimentation control is addressed by the Soil Erosion and Sediment Control Act (CGS §§22a-325 through 22a-335, inclusive). The primary goal of the Act is to reduce soil erosion from stormwater runoff and nonpoint sediment pollution from land being developed. Controlling soil erosion and sedimentation during construction is addressed through a combination of measures that are described in a site-specific Erosion and Sediment Control (E&SC) Plan. The basic principles of effective soil erosion and sediment control include:

- *Use effective site planning to avoid sensitive areas such as wetlands and watercourses*
- *Keep land disturbance to a minimum*
- *Stabilize disturbed areas*
- *Phase land disturbance on larger projects, starting subsequent phases after disturbed areas are stabilized*
- *Keep runoff velocities low*
- *Protect disturbed areas from stormwater runoff*
- *Properly install perimeter control practices*
- *Limit construction during months when runoff rates are higher due to decreased infiltration or extreme rainfall events*
- *Implement a thorough maintenance and follow-up program*
- *Assign responsibility for the maintenance program*

As shown in **Figure 3-1,** soil erosion and sediment control is a key component of any stormwater management strategy in order to reduce the impacts of stormwater runoff during construction activities. Although many of the vegetative, filtration, and infiltration stormwater management practices contained in this manual are based on the above principles, this manual does not address construction soil erosion and sediment control practices. Municipal ordinances contain specific soil erosion and sediment control requirements for developments disturbing more than one-half acre. Additionally, the 2002 revision of the *Connecticut Guidelines for Soil Erosion and Sediment Control, DEP Bulletin 34* (Connecticut Council on Soil and Water Conservation and the Connecticut Department of Environmental Protection, 2002) contains detailed technical guidance on specific erosion and sediment control practices and recommended procedures for developing an effective E&SC Plan. Copies of this guidance manual have been issued to each local Planning, Zoning, and Inland Wetlands and Watercourses Office.

3.6 Stormwater Treatment Practices

Stormwater treatment practices, which are the focus of the second half of this Manual, are primarily designed to remove pollutants from stormwater runoff. In addition to water quality treatment, these practices can also provide groundwater recharge, stream channel protection, and peak runoff attenuation. As described above, stormwater treatment practices should be selected and designed only after consideration of effective site planning/design and

Table 3-2 Stormwater Pollutant Removal Mechanisms

Mechanism	Pollutants Affected
Gravity settling of particulate pollutants	Solids, BOD, pathogens, particulate COD, phosphorus, nitrogen, synthetic organics, particulate metals
Filtration and physical straining of pollutants through a filter media or vegetation	Solids, BOD, pathogens, particulate COD, phosphorus, nitrogen, synthetic organics, particulate metals
Infiltration of particulate and dissolved pollutants	Solids, BOD, pathogens, particulate COD, phosphorus, nitrogen, synthetic organics, particulate metals
Adsorption on particulates and sediments	Dissolved phosphorus, metals, synthetic organics
Photodegradation	COD, petroleum hydrocarbons, synthetic organics, pathogens
Gas exchange and volatilization	Volatile organics, synthetic organics
Biological uptake and biodegradation	BOD, COD, petroleum hydrocarbons, synthetic organics, phosphorus, nitrogen, metals
Chemical precipitation	Dissolved phosphorus, metals
Ion exchange	Dissolved metals
Oxidation	COD, petroleum hydrocarbons, synthetic organics
Nitrification and denitrification	Ammonia, nitrate, nitrite
Density separation and removal of floatables	Petroleum hydrocarbons

source controls, which can reduce the volume of runoff and the size and cost of stormwater treatment.

Stormwater treatment practices are designed for small storms to achieve water quality objectives (i.e., smaller than a one-year return frequency storm), in contrast to drainage and flood control facilities, which are typically designed for the two-year and larger storms. However, many stormwater treatment practices can also be designed for flood control purposes and vice versa. Stormwater treatment practices can be integrated into the landscape, drainage or flood control system, and other spaces of development projects. When properly located, designed, and maintained, stormwater treatment practices can be amenities for, rather than detractions from, development projects.

Pollutant Removal Mechanisms

Stormwater treatment practices remove pollutants from stormwater through various physical, chemical, and biological mechanisms. **Table 3-2** lists the major stormwater pollutant removal mechanisms and the affected stormwater pollutants.

Since many pollutants in urban stormwater runoff are attached to solid particles, treatment practices designed to remove suspended solids from runoff will remove other pollutants as well. Exceptions to this rule include nutrients, which are often in a dissolved form, soluble metals and organics, and extremely fine particulates (i.e., diameter smaller than 10 microns), which can only be removed by treatment practices other than traditional separation methods.

Primary and Secondary Stormwater Treatment Practices

Stormwater treatment practices described in this Manual include both primary treatment practices, which provide demonstrated, acceptable levels of water quality treatment, and secondary treatment practices which are not suitable as stand-alone treatment facilities but can be used for pretreatment or as supplemental practices. This Manual includes five major categories of primary stormwater treatment practices:

- *Stormwater ponds*
- *Stormwater wetlands*
- *Infiltration practices*
- *Filtering practices*
- *Water quality swales*

Examples of secondary stormwater treatment practices described in the Manual include traditional practices such as dry detention ponds, vegetated filter strips and level spreaders, oil/particle separators, and deep sump catch basins. The Manual also includes innovative and emerging technologies as secondary treatment practices. These technologies are designed to remove a variety of stormwater pollutants, but have not been evaluated in sufficient detail to demonstrate the capability to meet established performance standards. Sizing and selection criteria for stormwater treatment practices are addressed in Chapter Seven and Chapter Eight, respectively.

New Development Versus Retrofits

Stormwater treatment practices can be implemented for new development projects as well as existing, developed sites. Retrofitting existing developments can improve water quality mitigation functions of older, poorly designed, or poorly maintained stormwater management systems. Incorporating stormwater retrofits into developed sites is typically more difficult than implementing treatment practices for new development due to the numerous site constraints associated with developed areas such as subsurface utilities, buildings, conflicting land uses, and maintenance access. Chapter Ten describes common stormwater retrofit options for existing development and redevelopment projects, including:

- *Stormwater collection system retrofits*
- *Stormwater management facility retrofits*
- *New stormwater controls at storm drain outfalls*
- *In-stream practices in existing drainage channels*
- *Parking lot stormwater retrofits*
- *Wetland creation and restoration*

3.7 Stormwater Quantity Control

Stormwater quantity controls include drainage and flood control. As shown in **Figure 3-1,** stormwater quantity and quality controls are related and complementary elements of an effective stormwater management strategy. Stormwater drainage systems can be designed to reduce the potential erosive velocity of stormwater runoff and maintain pre-development hydrology through infiltration and the use of vegetated conveyances, thereby preserving the water quality mitigation functions of a site. Similarly, stormwater treatment practices such as stormwater ponds and wetlands can provide dual flood control and water quality treatment benefits.

This Manual addresses the topics of drainage design and flood control as they relate to stormwater quality management. The Manual identifies stormwater treatment practices that also provide peak runoff attenuation and channel protection functions. However, this document is not intended to serve as a drainage or flood control design manual. Other recommended guidance documents and manuals on these topics include:

- *2000 Connecticut Department of Transportation Drainage Manual, October 2000*
- *Connecticut Department of Environmental Protection, Model Hydraulic Analysis, revised February 13, 2002*
- *Urban Hydrology for Small Watersheds, TR-55, Natural Resource Conservation Service (formerly Soil Conservation Service), June 1986*

In addition, municipal ordinances, as well as some DEP regulatory programs, contain specific stormwater quantity control requirements for land development projects, as described in Chapter One.

Drainage Design and Flood Control Principles for Water Quality

The traditional approach to drainage design has been to collect and remove runoff from the site as quickly as possible through the use of curbs, gutters, catch basins, and storm sewers, often resulting in the discharge of polluted runoff directly to receiving waters. While this approach effectively removes runoff from a site, it does not address water quality or downstream flooding and erosion issues. Similarly, the traditional approach to flood control has been to attenuate peak runoff to pre-development levels through the use of detention and retention ponds. While stormwater detention or retention facilities can effectively reduce peak discharge rates, they also typically prolong the duration of elevated flows and do not reduce runoff volumes unless infiltration is incorporated into their design. Historically, these facilities have not adequately addressed problems associated with water quality, runoff volume, and downstream channel erosion.

Drainage and flood control facilities should be designed according to the following principles to address water quality objectives:

- *Identify and assess existing stormwater runoff rates and volumes at the site, as well as downstream flooding and erosion concerns.*
- *Preserve pre-development hydrologic conditions, including peak discharge, runoff volume, groundwater recharge, and natural drainage paths.*
- *Reduce the potential for increases in runoff quantity by minimizing impervious surfaces and maximizing infiltration of stormwater runoff. Eliminate curbs where possible and encourage sheet flow from paved areas. If*

curbing is required, use Cape Cod curbing or other similar curbing, which allows amphibians to climb.

- *Encourage infiltration of stormwater through the use of vegetated depressions, swales, rain gardens and bioretention, and other vegetated drainageways to convey and hold stormwater and provide for a slow recharge to groundwater, where soils permit. Special care must be taken in areas of sensitive groundwater resources such as aquifer protection areas and groundwater supply wells in order to prevent their contamination. In addition, in areas with soil or groundwater contamination, the potential for infiltrated stormwater to mobilize contaminants must also be considered.*
- *Control increases in stormwater runoff volume and peak flows through properly designed and located stormwater management facilities. Manage stormwater so that both the volume and peak rate of runoff from the site after development does not exceed the volume and peak rate of runoff from the site prior to development.*
- *Encourage the development of watershed-based stormwater management strategies to effectively control the cumulative effects of increases in runoff volume and peak flows at critical locations throughout the watershed. Coordinate the timing of detention basin outflows to avoid increases in peak flows in downstream watercourses.*
- *Use adequate outlet protection at drainage outfalls to reduce discharge velocities, disperse flow, and prevent or reduce downstream erosion.*
- *Coordinate construction erosion and sediment control measures with post-construction stormwater management measures. For example, a sediment basin designed to trap sediment during the construction phase of a project may sometimes be converted to a detention basin or stormwater treatment facility to meet peak runoff attenuation or water quality mitigation objectives following construction.*
- *Retain on-site the volume of runoff generated by the first inch of rainfall from areas adjacent to or within 500 feet of tidal salt marshes and estuarine waters. Excessive quantities of fresh water can be a pollutant to tidal wetlands and cause a decrease in vegetative diversity and wetland productivity.*
- *Protect wetland and watercourse resources from stormwater discharges. Do not drain stormwater directly to a wetland or watercourse or to a municipal storm drainage system that drains directly to a wetland or watercourse without adequate stormwater treatment. Protect wetlands, watercourses, and submerged aquatic vegetation from scour.*

3.8 Watershed Management

Stormwater management is most effectively undertaken in the context of a watershed management plan. A watershed management plan is a comprehensive framework for applying management tools in a manner that achieves the water resources goals for the watershed as a whole (CWP, 1998). Typically, watershed management plans are developed from watershed studies undertaken by one or more municipalities located within the watershed. The watershed approach has emerged over the past decade as the recommended approach for addressing nonpoint source pollution problems, including polluted stormwater runoff. Watershed planning offers the best means to:

- *Address cumulative impacts derived from a number of new land development projects*
- *Plan for mitigation to address cumulative impacts from existing developments*
- *Focus efforts and resources on identified priority water bodies and pollutant sources in a watershed*
- *Achieve noticeable improvements to impaired waters or waters threatened with impairment*

The watershed approach is built on three main principles. First, the target watersheds should be those where stormwater impacts pose the greatest risk to human health, ecological resources, desirable uses of the water, or a combination of these. Second, parties with a stake in the specific local situation (i.e., stakeholders) should participate in the analysis of problems and the creation of solutions. Third, the actions undertaken should draw on the full range of methods and tools available, integrating them into a coordinated, multi-organization attack on the problems. The watershed approach has the following significant advantages over traditional piecemeal approaches to stormwater management that require individual land developments to provide on-site stormwater management facilities (adapted from Aldrich, 1988):

Lower capital and O&M cost: Typically, watershed management plans yield fewer and larger stormwater management facilities. Economies of scale are achievable in capital costs and especially in O&M. Strategic placement of regional facilities permits concentrating funds on areas where potential benefits are greatest. Cost sharing arrangements significantly reduce the net cost of stormwater management to the community as a whole.

Increased effectiveness on a watershed-wide basis: Often different portions of watersheds require different types of stormwater controls. Watershed planning permits the siting of a variety of on-site and regional facilities in locations where the greatest benefits are achieved.

Greater use of nonstructural measures: Often the most practical stormwater controls involve nonstructural measures such as land acquisition, floodplain zoning, subdivision drainage ordinances, and land use controls. Watershed planning provides a coordinated, comprehensive framework and decision-making process to allow the effective implementation of these measures.

Less risk of negative "spillover" effects: The piecemeal approach may adequately solve localized drainage problems, but seldom addresses downstream impacts. Thus, dynamic interactions between upstream drainage improvements may actually increase downstream flooding. An objective of watershed planning is to account for these upstream interactions and achieve solutions to both localized and regional stormwater management concerns.

Watershed management plans should include recommended criteria for stormwater source controls and treatment practices in the watershed. These criteria are based on watershed-specific factors such as physical attributes, land use, pollution sources, and sensitive receptors, and are the basis for selecting and locating stormwater controls in the watershed. At a minimum, a watershed management plan should contain the elements listed in **Table 3-3** to address stormwater-related issues.

The watershed management plan should address integrating flood control and stormwater management controls with community needs, including open space, aesthetics, and other environmental objectives such as habitat or river restoration. This synchronization with other programs can create better funding opportunities and enhance the overall benefit of the stormwater management practices in the watershed.

On-Site Versus Regional Approaches

Watershed management plans can identify conditions and locations in the watershed where regional stormwater management facilities may be more appropriate or effective than on-site controls. On-site and regional stormwater management approaches are illustrated schematically in **Figure 3-2.** These approaches apply to both stormwater quality and quantity controls.

In the on-site approach, land developers have responsibility for deploying treatment practices and runoff controls at individual development sites. Developers are responsible for constructing on-site stormwater management facilities to control stormwater pollutant loadings and runoff from the site. The local government is responsible for reviewing the design of stormwater management facilities relative to specified design criteria, for inspecting the constructed facilities to ensure conformance with the design, and for ensuring that operation and maintenance plans are implemented for the facilities (Novotny, 1995).

The regional approach involves strategically siting stormwater management facilities to control stormwater runoff from multiple development projects or large drainage areas. Local or regional governments assume the capital costs for constructing the regional facilities. Capital costs are typically recovered from upstream developers as development occurs. Individual regional facilities are often sited and phased in as development occurs according to a comprehensive watershed management plan. Municipalities generally assume responsibility for operation and maintenance of regional stormwater facilities (Novotny, 1995).

Both approaches have a number of advantages and disadvantages, which are summarized in **Table 3-4.** Most of the advantages of the regional approach can be attributed to the need for fewer stormwater management facilities that are strategically located throughout the watershed (Novotny, 1995). However, the on-site approach addresses stormwater pollution close to its source, offers greater opportunities to preserve pre-development hydrologic conditions, and reduces the overall volume of stormwater runoff. Historically the on-site approach to stormwater management has been more common in Connecticut. The major drawbacks that have limited the widespread use of the regional approach include significant required advanced planning, financing, and land acquisition. Local governments must finance, design, and construct regional stormwater facilities before the majority of the watershed is developed, with reimbursement by developers over build-out periods of many years (WEF and ASCE, 1992). Due to these limitations, the regional approach generally is more appropriate for:

- *Highly developed watersheds with severe water quality and flooding impacts, where stormwater controls for new development alone cannot adequately address the impacts in these areas*
- *Watersheds where the timing of peak runoff may increase downstream flooding if on-site peak runoff attenuation criteria are applied uniformly throughout the watershed*

(Pennsylvania Association of Conservation Districts et al., 1998). In most watersheds, a mix of regional and on-site controls is desirable and has the greatest potential for success when implemented as part of a comprehensive watershed management plan. (DEP, 1995).

Table 3-3 Elements of a Watershed Management Plan

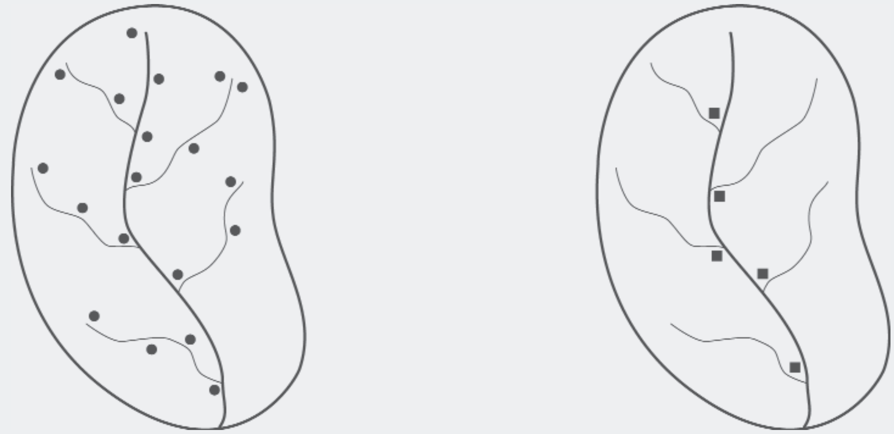
Plan Elements	
Watershed delineation and identification of watershed characteristics such as topography, soils, surficial geology, impervious cover, and land use (current and projected)	A runoff hydrograph analysis of the watershed for floods of an appropriate duration, including a 24 hour event, with average return frequencies of 2, 10, 25, and 100 years for existing and future land uses
Inventory of flood hazard areas as identified by Flood Insurance Studies or DEP, plus historic floods and damages	The relationship between the computed peak flow rates and gauging station data, with modification or calibration of the hydrographs to obtain a reasonable fit where necessary
An evaluation of watercourses, including areas of limited flow capacity, bank or bed erosion, sediment deposition, water quality, principle water uses and users, recreation areas, morphology classification, and channel stability	Identification of the peak rate of runoff at various key points in the watershed, and the relative timing of the peak flows
An inventory and evaluation of hydraulic structures, including culverts, bridges, dams and dikes with information on their flow capacity and physical condition	Identification of points in the watershed where hydraulic structures or watercourses are inadequate under existing or anticipated future conditions
An inventory of significant water storage areas, including principal impoundments, floodplains, and wetlands	Recommendations on how the subwatershed's runoff can be managed to minimize any harmful downstream (flooding) impacts
Identification of sensitive and impaired wetlands and waterbodies	Existing and projected future pollutant loads, impacts of these loads, and pollution reduction goals
Evaluation of functional value of wetlands to identify sensitive and high quality wetland resources	Existing and projected aquatic habitat disturbances and goals for habitat restoration
Sensitive groundwater recharge or aquifer protection areas	Recommendations for watershed-specific stormwater treatment controls, conceptual design, and operation and maintenance (O&M) needs and responsibilities
Identification of existing problem land uses and impacts on water quality	Water quality monitoring program
Land use restrictions in sensitive areas	Prioritized implementation plan for recommendations
Inventory of local wetlands, conservation, planning and zoning, and subdivision regulations of the watershed municipalities to identify potential regulatory changes for addressing stormwater impacts	Identification of public water supply watershed areas and DEP-delineated aquifer recharge areas.

Table 3-4
Comparison of On-Site and Regional Stormwater Management Approaches

Approach	Advantages	Disadvantages
On-Site	❍ Requires little or no advanced planning ❍ Addresses stormwater pollution close to its source, thereby reducing the volume of stormwater runoff and the need for treatment controls ❍ Provides greater groundwater recharge benefits	❍ Results in a large number of facilities that may not be adequately maintained by developers or home-owners ❍ Consumes on-site land that could be used for other purposes ❍ May increase downstream flooding and quantity control problems
Regional	❍ Reduced capital costs through economies of scale in designing and constructing regional facilities ❍ Reduced maintenance costs because there are fewer facilities to maintain ❍ Greater reliability because regional facilities are more likely to receive long-term maintenance ❍ Nonpoint pollutant loadings from existing developed areas can be affordably controlled at the same regional facilities that are sited to control future development ❍ Regional facilities provide greater opportunities for multipurpose uses such as recreational and aesthetic benefits, flood control, and wildlife ❍ Can be used to treat runoff from public streets which is often missed by on-site facilities ❍ Identifies opportunities to reduce regional stormwater pollutant loadings and provides a schedule for imple-menting appropriate controls	❍ Significant advanced watershed planning required ❍ Requires up-front financing ❍ Requires land availability and acquisition ❍ May promote "end-of-pipe" treatment mentality rather than the use of on-site controls to reduce stormwater runoff volume and the need for stormwater treatment ❍ Greater administrative responsibility for municipali-ties and local governments ❍ Some treatment practices are not appropriate for large drainage areas (swales, filter strips, media fil-ters, and oil/particle separators)

Source: Adapted from Novotny, 1995; DEP¸ 1995; Pennsylvania Association of Conservation Districts et al., 1998; WEF and ASCE, 1992.

Figure 3-2 On-site and Regional Stormwater Treatment Approaches



Source: Adapted from Novotny, 1995.

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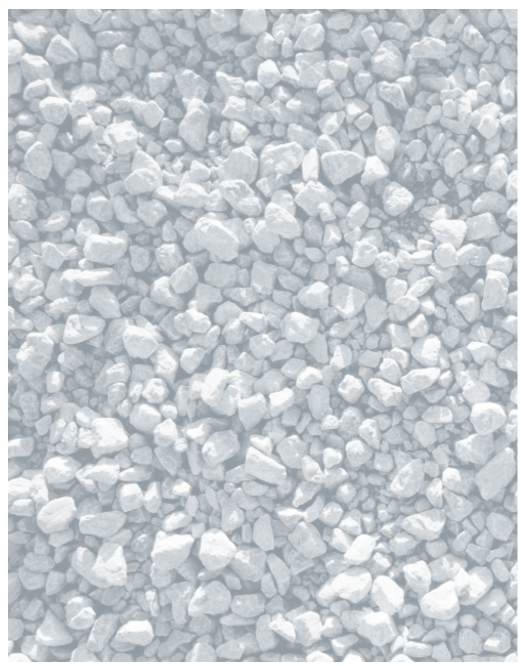
Chapter 4
Site Planning and Design



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4.1 Introduction

Careful site planning at the outset of a project is the most effective approach for preventing or reducing the potential adverse impacts from development. Site planning is a preventive measure that addresses the root causes of stormwater problems. Effective site layouts and designs that preserve natural features as well as natural hydrologic and water quality functions can limit water quality impacts and the need for costly structural stormwater controls, thereby reducing the costs of development. Other potential benefits of effective site planning include preservation of open space, enhanced aesthetic and recreational value, reduced downstream flooding, and enhanced land values.

Site planning and design is a complex process involving a variety of considerations such as zoning regulations (e.g. setbacks, Floor Area Ratio allowances, allowable building density, and height restrictions) and impacts to traffic, wetlands, and the environment. Site planning is undertaken by the developer or project proponent in conjunction with local and/or state review agencies, typically local Planning, Zoning, and Inland Wetlands Commissions and, in some instances, the Connecticut Department of Environmental Protection (DEP) or federal agencies such as the U.S. Army Corps of Engineers. Due to the complexities of site planning and design, the most effective site planning process occurs through a collaborative effort between developers and the review agencies before and throughout the review process.

This chapter addresses recommended site planning concepts and practices that can be incorporated into the design of new projects to provide water quality and quantity benefits and reduce the need for or size of structural stormwater controls. This chapter does not address comprehensive land use planning (master planning, zoning, open space, conservation easements, etc.) which is beyond the scope of this Manual. However, the site planning concepts and practices presented in this chapter should be implemented through existing local land use ordinances and state regulations and programs. Local and state review agencies should encourage the implementation of these practices through the site plan review process. In many instances, communities may need to re-evaluate local codes and ordinances to effectively promote the use of the practices described in this chapter. These design concepts are encouraged by DEP, as well as by the Connecticut Department of Public Health (DPH) for protection of water supplies in public drinking water supply watershed areas.

4.2 Site Planning and Design Concepts

The concepts presented in this section are central to effective site planning and design for stormwater management and environmental resource protection. Each of these concepts is based on the fundamental objective of preserving a site's natural hydrologic conditions. As discussed in Chapter Two, the hydrologic conditions and pollutant removal functions of a site can be altered significantly as a result of development. The traditional approach to site drainage has been to remove runoff from the site as quickly and efficiently as possible through the use of storm sewers and structural stormwater conveyances, and to provide detention facilities to manage increases in peak flows. This approach severely reduces the natural hydrologic and water quality functions of the site and contributes to the adverse environmental impacts discussed in Chapter Two.

A guiding principle of effective site planning is to preserve pre-development hydrologic conditions such as:

- *Runoff volume and rate*
- *Groundwater recharge*
- *Stream baseflow*
- *Runoff water quality*

This can be accomplished through a number of techniques that should be integrated into the site planning and design process wherever possible. These techniques are described in the following sections of this chapter. In collaboration with DEP's NPS Program, the University of Connecticut Cooperative Extension System's Nonpoint Education for Municipal Officials (NEMO) Project offers assistance to Connecticut municipalities in implementing these site planning and design strategies. (See Additional Information Sources at the end of this chapter or visit http://www.nemo.uconn.edu).

Designing the Development to Fit the Terrain

Developments that are designed to “fit the terrain” of the site require significantly less grading and soil disturbance than those that are designed without regard for the existing topography. Road patterns should match the landform by placing roadways parallel to contour lines where possible. In doing so, natural drainageways can be constructed along street rights-of-way, thereby reducing the need for storm pipes. Open space development, allowable in many municipalities, can help preserve large natural areas and open space as well as make it possible to design around topographical constraints.

Limiting Land Disturbance Activities

Land disturbance activities such as clearing and grubbing, excavation, and grading result in erosion of exposed soils, increased sediment loadings, as well as increased volumes of runoff from a site. Limiting the land area disturbed by development can only be addressed comprehensively at the site planning level (Schueler, 1995). Land disturbance activities should be limited to only those areas absolutely necessary for construction purposes, in keeping with the natural features of the site, and should be clearly delineated in the field prior to construction. Land disturbance activities in proximity to wetlands, watercourses, steep slopes, and other sensitive resource areas should be avoided, or minimized if they cannot be avoided. Areas outside the disturbed zone should retain natural vegetation. This approach is more successful on larger lots where large areas of undeveloped land can be preserved. The successful application of this approach is more difficult and less practical on small lots in heavily developed areas (NJDEP, 2000).

Reducing or Disconnecting Impervious Areas

Reducing and disconnecting impervious surfaces are effective methods for preserving pre-development hydrology. Reducing impervious coverage on a site directly limits the adverse impacts associated with impervious coverage. On a watershed basis, reductions in impervious coverage contribute directly to the ecological health of streams and receiving waters, as described in Chapter Two. Impervious surfaces that are not directly connected to the drainage collection system contribute less runoff and smaller pollutant loads than hydraulically connected impervious surfaces. Isolating impervious surfaces also promotes infiltration of stormwater runoff. Specific techniques for reducing or disconnecting impervious areas for road and lot development are described in **Section 4.3 Alternative Site Design.**

Preserving and Utilizing Natural Drainage Systems

The goal of traditional drainage design, to collect and convey stormwater runoff from the site as efficiently as possible, is in direct conflict with the objectives of water quality design, which is to slow down and attenuate runoff to allow filtration, infiltration, biological uptake, and settling of pollutants. Natural drainage features such as vegetated swales and channels and natural micro-pools or depressions should be preserved or incorporated into the design of a site to take advantage of their ability to infiltrate and attenuate flows and filter pollutants. The use of natural overland drainage features such as stabilized swales, where soil and hydraulic conditions allow, and the discharge of stormwater in a diffuse manner from level spreaders should be encouraged as an alternative to traditional storm sewer systems. Consistent with this approach is to design roads and parking areas at higher elevations in the landscape and locate existing swales along back lot lines within drainage easements (Pennsylvania Association of Conservation Districts et al., 1998). Natural low areas or depressions in the landscape should be preserved where possible to maintain infiltration of runoff in these areas similar to pre-development conditions.

Providing Setbacks and Vegetated Buffers

Setbacks and vegetated buffers provide protection of adjacent natural resources from areas of intensive development. A setback is the regulated area between the development and a protected area such as a wetland. A vegetated buffer is an area or strip of land of permanent undisturbed vegetation adjacent to a water body or other resource. Buffers protect resources from adjacent development during construction and after development by filtering pollutants in runoff, protecting water quality and temperature, providing wildlife habitat, screening structures and enhancing aesthetics, and providing access for recreation. Characteristics such as width, target vegetation, and allowable uses within buffers are managed to ensure that the goals designated for the buffer are achieved (Center for Watershed Protection, 1998b). Buffers along watercourses also serve to function as greenways that provide for connectivity of open space areas, allowing the movement of wildlife and the opportunity for passive recreation. The dual benefits that buffers provide for the protection of water quality from stormwater runoff and the creation of greenways are extremely important and complementary. **Table 4-1** summarizes the benefits that can be achieved by buffer systems.

As a general rule, one hundred feet of undisturbed upland along a wetland boundary or on either side of a watercourse is recommended as a minimum buffer width depending on the slope and sensitivity of the wetland or watercourse. A conceptual three-zone

Table 4-1 Benefits of Watercourse Buffers

Benefit	
Reduce nuisance drainage problems and complaints	Prevent disturbance of steeps slopes
Allow for lateral movement of streams	Mitigate stream warming
Provide flood control	Preserve important terrestrial habitat
Reduce stream bank erosion	Supply conservation corridors
Increase property values	Maintain essential habitat for amphibians
Enhance pollutant removal	Fewer barriers to fish migration
Provide opportunities for Greenways	Discourage excessive storm drain enclosures/channel hardening
Provide food and habitat for wildlife	Provide space for stormwater treatment practices
Protect associated wetlands	Allow for future restoration

Source: Adapted from Center for Watershed Protection, 1998a.

stream buffer system designed for protecting aquatic resources while providing flexibility for development is shown in **Figure 4-1** (Center for Watershed Protection, 1998a, adapted from Welsh, 1991). Each zone can have designated functions, width requirements, and management requirements.

Minimizing the Creation of Steep Slopes

Development or disturbance of steep slopes creates the potential for erosion and significant sediment loadings in the absence of effective stabilization measures. Development destroys vegetation, root systems, and soil structure (Pennsylvania Association of Conservation Districts et al., 1998). Although the definition of steep depends on soil characteristics and erodibility, slopes steeper than 10 percent, or even flatter slopes with highly erodible soils, typically require stabilization. The area and duration of disturbance on steep slopes should be minimized. Soil stabilization measures should be implemented in accordance with local erosion and sedimentation control ordinances, as well as the *Connecticut Guidelines for Soil Erosion and Sediment Control* (Connecticut Council on Soil and Water Conservation and the Connecticut Department of Environmental Protection, 2002).

Maintaining Pre-Development Vegetation

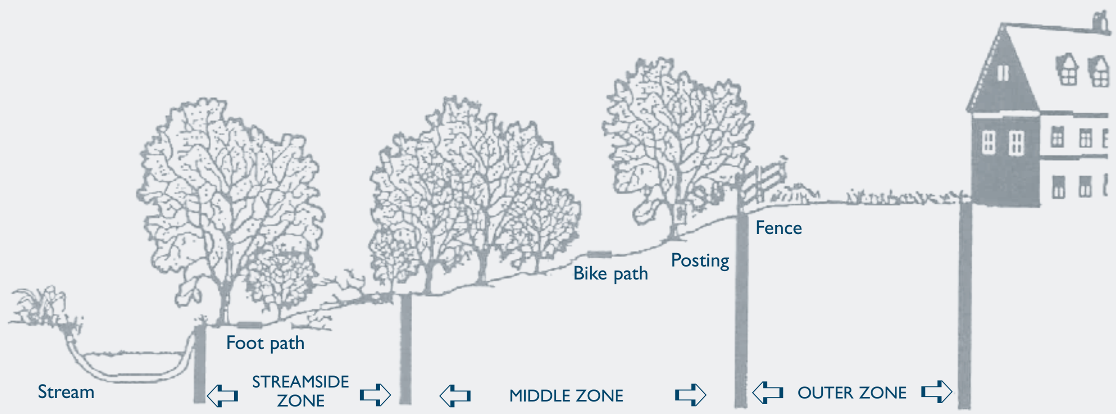
Pre-development vegetation should be maintained to the extent possible, especially on streambanks that might otherwise be cleared for view enhancement. Vegetation intercepts rainfall and promotes evapotranspiration, thereby reducing the volume of runoff from a site. In addition to providing erosion control, trees also provide shade to minimize thermal impacts to surface waterbodies. Trees and other vegetation can be incorporated into a site by planting additional native vegetation, clustering tree areas, and conserving existing native vegetation. Wherever practical, trees should be incorporated into community open space, street rights-of-way, parking lot islands, and other landscaped areas.

4.3 Alternative Site Design

A variety of innovative site design practices have been developed as an alternative to traditional development to control stormwater pollution and protect the ecological integrity of developing watersheds. These alternative site design practices are based on the concepts described in the previous section, such as reducing site imperviousness and disturbed areas, preserving natural site features, and promoting infiltration through the use of natural vegetated conveyances. Research has demonstrated that alternative site design can reduce impervious cover, runoff volume, pollutant loadings, and development costs when compared to traditional development (Center for Watershed Protection, 2000). **Table 4-2** summarizes the documented benefits of alternative site design.

Several factors have limited the widespread application of alternative site design principles in Connecticut and other parts of the country. Alternative site design is a relatively new concept, dating back only to the early 1990s, and involves fundamental changes to development practices that

Figure 4-1 Typical Three-Zone Urban Buffer System



Source: Center for Watershed Protection, 1998a (adapted from Welsh, 1991).

are typically dictated by a complex mix of local zoning, subdivision, and building ordinances. Typical conventional development rules are often inflexible and restrict development options regarding site plan parameters. Consumer demand for wide streets, long driveways, expansive parking lots, and large-lot subdivisions, whether perceived or actual, has also limited the use of alternative site design concepts by the development community.

This Manual encourages the use of alternative site design practices to the extent that local development rules will allow, to achieve the benefits listed in **Table 4-2**, as well as to reduce the need for and size of end-of-pipe stormwater treatment. However, the Manual also recognizes that communities may need to re-evaluate local codes and ordinances to overcome these challenges and effectively promote the widespread use of alternative site design practices. Recommended sources of information on how communities can modify local development rules to reduce impervious cover, conserve natural areas, and prevent stormwater pollution are provided at the end of this chapter.

A unique demonstration project is currently underway in Connecticut to compare the stormwater runoff quantity and quality emanating from traditional and alternative residential development sites. The Jordan Cove Urban Watershed Monitoring Project is a paired-watershed monitoring study funded, in part, through the Connecticut Department of Environmental

Table 4-2 Benefits of Alternative Site Design

Benefit	
Protection of surface water quality	A more aesthetically pleasing and naturally attractive landscape
Reduction of stormwater pollutant loads	Safer residential streets
Reduction of soil erosion during construction	More sensible locations for stormwater facilities
Reduced development construction costs	Easier compliance with wetland and other resource protection regulations
Increases in local property values and tax revenues	Neighborhood designs that provide a sense of community
More pedestrian friendly neighborhoods	Urban wildlife habitat through natural area preservation
More open space for recreation	Protection of sensitive forests, wetlands, and habitats

Source: Adapted from Center for Watershed Protection, 1998a.

Protection and by the U.S. Environmental Protection Agency's Section 319 National Monitoring Program (NMP). The study is examining differences in runoff quantity and quality from three watersheds located in Waterford, Connecticut, including an existing control watershed with traditional residential development and a newly constructed residential development split into two distinct neighborhoods, one with traditional subdivision design and the other with open space design and a variety of Low Impact Development practices. Post-construction flow and water quality monitoring will continue for three years after build-out. The results of this are expected to provide quantitative, real-world comparisons of the benefits and challenges of alternative site design.

A number of recommended alternative site design practices are described in the following sections. These practices are loosely organized into two categories:

- *Streets and Parking Lots*
- *Lot Development*

4.3.1 Streets and Parking Lots

These practices address the design of streets, parking lots, and other impervious surfaces associated with vehicular traffic in residential and commercial areas.

Reducing Street Widths

Many residential streets are wider than necessary. Reducing the width of streets can reduce impervious surfaces in a watershed. Other benefits of narrower streets include reduced clearing and grading impacts, reduced vehicle speeds (i.e., "traffic calming"), lower maintenance costs, and enhanced neighborhood character. Reducing or eliminating on-street parking can reduce road surfaces and overall site imperviousness by 25 to 30 percent (Sykes, 1989). In some areas, curbing can be eliminated to encourage sheet flow and facilitate the use of vegetated roadside swales. Eliminating curbing in residential and rural areas with nearby vernal pool habitat also allows amphibian migration across roads. An alternative to eliminating curbing is the use of Cape Cod curbing, which allows amphibians to climb.

Residential streets should be designed for the minimum required pavement width needed to support travel lanes, on-street parking, as well as emergency, maintenance, and service vehicle access. Residential street widths should be based on the following four variables:

- **Traffic Volume:** *A simple rule of thumb regarding traffic volume is the fewer the vehicles, the narrower the road may be. Many communities require a minimum width of 32 to 34 feet of pavement or two, adjacent 16- to 17-foot travel lanes for all roads. Research shows that 20-to 24-foot road widths (two 10- to 12-foot travel lanes) are adequate for most local roads.*

Table 4-3 Minimum Residential Roadway Width Guidelines

Terrain Classification[1]	Level			Rolling			Hilly		
Development Density[2]	Low	Med	High	Low	Med	High	Low	Med	High
Right of Way Width (ft)	50	60	60	50	60	60	50	60	60
Pavement Width (ft)	20-24	28	36	20-24	28	36	28	28	36
Sidewalks and Bicycle Paths (ft)	0	4	5	0	4	5	0	4	5

Source: Guidelines for Residential Subdivision Street Design, Institute of Transportation Engineers, Washington DC, 1993, in University of Connecticut, Transportation Institute, Technology Transfer Center Fact Sheet.
1Terrain Classification: Level – grade of 0% to 8%, Rolling – >8% to 15%, Hilly – >15%
2Development Density: Low – 2 or fewer dwelling units/acre, Med – >2 to 6 dwelling units/acre, High – more than 6 dwelling units/acre

- **Design Speed:** *Slower design speeds allow for narrower road widths. Local residential roads should be designed to provide safe access to homes. Research indicates that as residential streets widen, accidents per mile per year increase exponentially and that the safest residential street width is 24 feet (Swift et al., 1998).*

- **Lot Width:** *As a general rule, large lots with long front yards require less on-street parking since large lots by their very nature have enough area to accommodate on-site parking. Roads serving large lots do not have to be designed with on-street parking lanes and therefore can be narrower.*

- **Parking Needs:** *The need for on-street parking is often used to justify wider residential streets. Roads designed to provide overflow parking from adjacent lots require one or two additional parking lanes. However, not all roads are designed to accommodate on-street parking and therefore do not require additional parking lanes.*

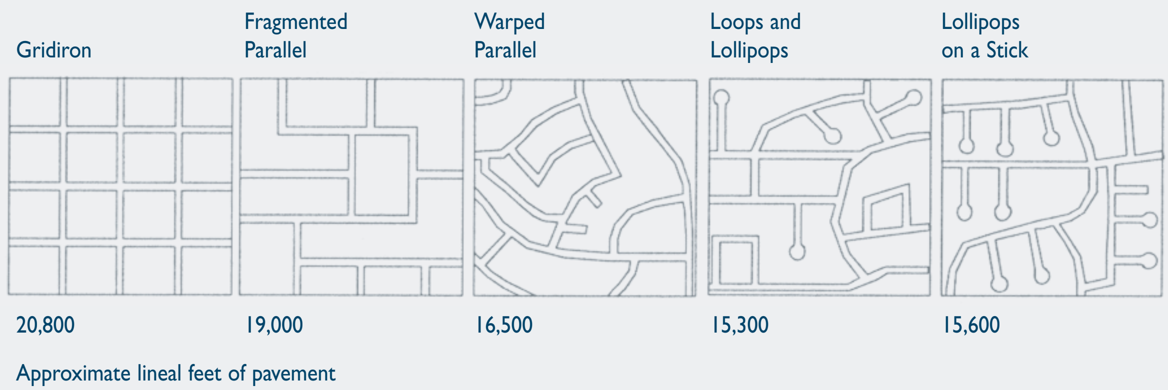
(NEMO Technical Paper #9, Roads, Gibbons 1998a): The standard 50- to 60-foot right-of-way width is recommended to provide adequate emergency access and parking. However, the paved portion of the right-of-way should be minimized to the extent possible. **Table 4-3** presents minimum roadway width guidelines for residential subdivision street design.

Reducing Street Lengths through Alternative Street Layout

Street lengths and, therefore, total site imperviousness can be reduced through alternative street and subdivision layouts. **Figure 4-2** illustrates how alternate layouts can reduce roadway impervious surfaces by up to 26 percent.

No single street layout is appropriate for all residential development. Roadway layout is highly dependent on site topography, density, traffic volume, and overall subdivision design. Residential areas with low traffic volume and minimal topographical relief have the most flexibility in design. In Connecticut, a majority of residential subdivisions use the "loops and lollipops" and "lollipops on a stick" configurations. These road layout designs utilize cul-de-sacs, loops, and short feed streets to accommodate the contours and natural features of a site. Open space development, a compact form of development that concentrates density on one portion of the site in exchange for reduced density elsewhere, also lends itself to reduced street lengths. Grid-based street layouts tend to have relatively longer overall street lengths. The exception is traditional neighborhood design, which incorporates community open space, a variety of housing types, and mixed land uses in a single project to emulate the characteristics of smaller, older communities (Center for Watershed Protection, 1998a).

Figure 4-2 Alternative Street Layout



Source: Prince George's County, Maryland, 1999 (adapted from ULI, 1980).

Alternative Cul-de-sac Design

Cul-de-sacs have a large bulb located at the closed end of the street to enable emergency and service vehicles to turn around without having to back up. Traditional cul-de-sacs utilize a large-radius, paved turnaround that can dramatically increase the imperviousness of a residential subdivision. Alternatives to this traditional design include turnaround bulbs with smaller radii and the use of a landscaped island (i.e., rain garden or bioretention area) in the center of the cul-de-sac to collect rainwater from the end of the roadway.

Reducing the radius of a typical cul-de-sac turnaround from 40 to 30 feet can reduce impervious coverage by nearly 50 percent (Schueler, 1995). A 30-foot radius will accommodate most vehicles and reduce pavement. Cul-de-sac bioretention islands have been used successfully in various parts of the country, including a demonstration subdivision in Waterford, Connecticut. These islands can be landscaped with low maintenance perennials or shrubs appropriate for the soil and moisture conditions. Bioretention and rain gardens are discussed later in this chapter. If a cul-de-sac island is used, the cul-de-sac radius should allow for a minimum 20-foot wide road. To make turning easier, the pavement at the rear center of the island may be wider (Metropolitan Council, 2001). **Figure 4-3** illustrates these cul-de-sac design concepts.

Reducing the Use of Storm Sewers

The use of swales and other vegetated open channels should be encouraged in residential streets, parking lots, and back yards in place of conventional storm drain systems. Open vegetated channels provide the potential for infiltration and filtering runoff from impervious surfaces, as well as groundwater recharge and reduced runoff volume. In addition to the water quality benefits that open vegetated channels provide, these systems are also significantly less expensive to construct than conventional storm drain systems. The use of vegetated drainage swales in lieu of conventional storm sewers may be limited by soils, slope, and development density. In many cases, subdivision ordinances discourage or prohibit the use of open vegetated channels for roadside drainage due to concerns over inadequate drainage, maintenance issues, pavement stability, and nuisance insects (if water is allowed to stand for longer than 7 to 10 days). This practice requires educating local citizens and public works officials who expect runoff to disappear quickly after a rainfall event (Pennsylvania Association of Conservation Districts et al., 1998).

Reducing Parking Lot Size

Parking lots are the largest component of impervious cover in most commercial and industrial land uses (Center for Watershed Protection, 1998a). The number of parking spaces at a site is determined by local parking ratios which dictate the minimum number of spaces per square foot of building, dwelling units, persons, or similar measure. Parking ratios are typically set as minimums, not maximums, thereby allowing for excess parking. In addition, local parking codes often require standard parking stall dimensions to accommodate larger vehicles. A recent parking study conducted for the Northwestern Connecticut Council of Governments and Litchfield Hills Council of Elected Officials demonstrated that, in most cases, demand for parking is less than what is required by zoning, while more parking than required by zoning is provided. Big box retail parking lots typically have more excess parking than for any other land use (*Draft Northwest Connecticut Parking Study, Fitzgerald & Halliday, Inc. 2002*).

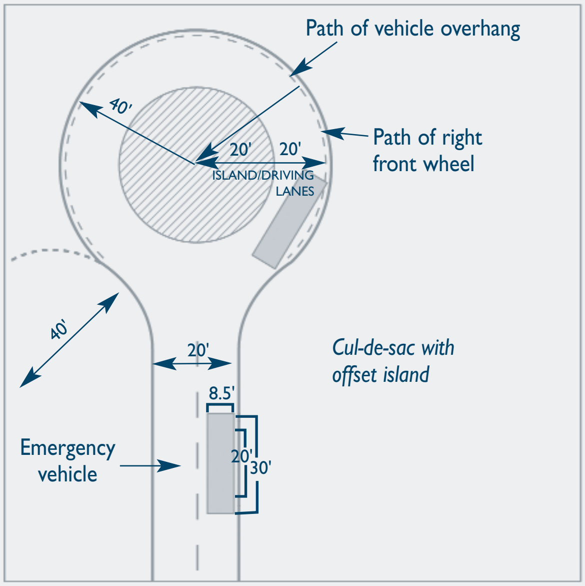
Reducing minimum parking requirements, establishing or enforcing maximum parking lot ratios, reducing parking stall size, and incorporating alternative internal geometry or traffic patterns through the use of one-way aisles and angled parking stalls can reduce parking lot size and impervious cover. Parking demand ratios should be based upon site-specific parking generation studies, where feasible (Metropolitan Council, 2001). Incorporation of bioretention facilities or other stormwater treatment devices (i.e., sand filters, vegetated swales, filter strips) into parking lot design features such as perimeter and median strips can further reduce pollutant loads from these areas. **Figure 4-4** is a schematic of an alternative parking lot design.

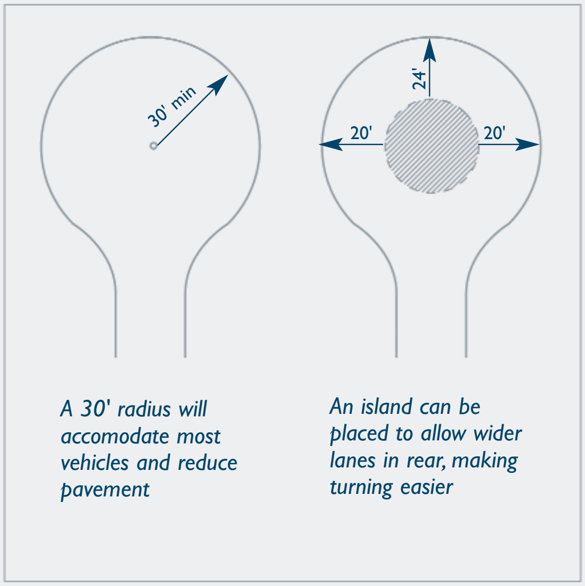
Shared parking is a similar strategy that reduces the number of parking spaces needed by allowing adjacent land uses to share parking lots. For shared parking to operate successfully, the participating facilities should be in close proximity to each other and have peak parking demands that occur at different times during the day or week (Center for Watershed Protection, 1998a). Examples of facilities with different daily peak hours and potential candidates for shared parking include professional offices, banks, and retail stores (daytime peak hours) and theaters, restaurants, and bars (evening peak hours). Use of phantom parking is also recommended. Under a phantom parking strategy, sufficient land is reserved for projected parking requirements, but only a portion of the parking area is constructed at the outset. Additional areas are paved on an as-needed basis.

Using Permeable Paving Materials

Permeable paving materials are alternatives to conventional pavement surfaces designed to increase infiltration and reduce stormwater runoff and pollutant loads. Alternative materials include modular concrete paving blocks, modular concrete or plastic lattice, cast-in-place concrete grids, and soil enhancement technologies. These practices increase a site's load bearing capacity and allow grass growth and infiltration (Metropolitan Council, 2001). Stone, gravel, and other low-tech materials can also be used as

Figure 4-3 Alternative Cul-de-sac Design

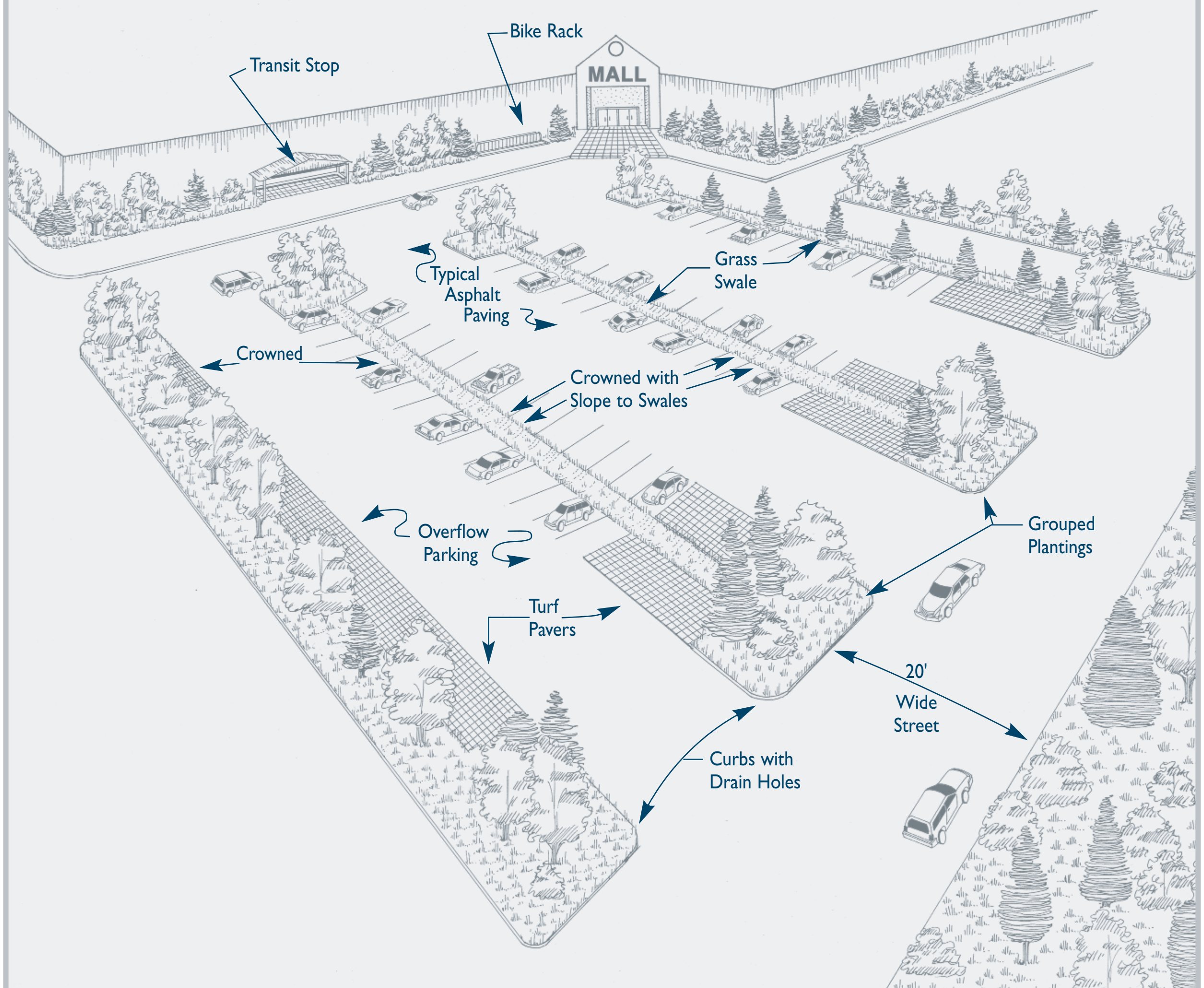


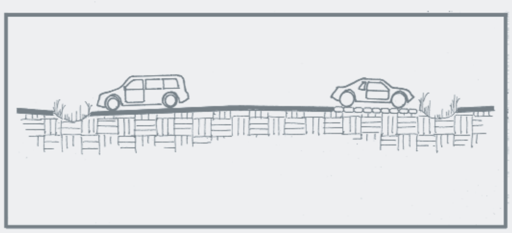


Cul-de-sac infiltration island accepts stormwater from surrounding pavement. Note flat curb.

Source: Metropolitan Council, 2001 (adapted from Schueler, 1995 and ASCE, 1990).

Figure 4-4 Alternative Parking Lot Design Schematic





Source: Metropolitan Council, 2001 (adapted from Robert W. Droll, ASLA, in Wells 1994).

alternatives for low traffic applications such as driveways, haul roads, and access roads.

Porous asphalt or concrete, also known as porous pavement, is similar to conventional asphalt but formulated to have more void space for greater water passage through the material. Traditionally, porous pavement has had limited application in cold climates such as Connecticut due to the potential for clogging as a result of sand application. Porous pavement has been successfully used for some parking lot applications in New England where the underlying soils are sufficiently permeable. One example is a parking lot demonstration project at Walden Pond State Reservation in eastern Massachusetts.

While permeable paving materials can make sense in many parking lot designs, site-specific factors such as accessibility, soils, maintenance, and long-term performance must be carefully considered. Permeable paving materials are most appropriate in areas of low traffic volume (e.g., generally less than 500 average daily trips or ADT) such as roadside rights-of-way, emergency access lanes, delivery access routes, residential driveways, and overflow parking. Chapter Eleven of this Manual contains additional siting and design guidance for permeable pavement materials.

4.3.2 Lot Development

These alternative design practices address the size, shape, density, and appearance of residential development.

Maintaining Pre-Development Vegetation

Pre-development vegetation should be maintained to the extent possible. Vegetation intercepts rainfall and promotes evapotranspiration, thereby reducing the volume of runoff from a site. Trees and other vegetation can be incorporated into a site by planting additional vegetation, clustering tree areas, and conserving native vegetation. Wherever practical, trees should be incorporated into community open space, street rights-of-way, parking lot islands, bioretention areas, and other landscaped areas.

Open Space Development

Open space development, also known as conservation or cluster development, can reduce the amount of impervious area for a given number of lots. Open space development is a compact form of development that concentrates density in one portion of the site in exchange for reduced density elsewhere (Center for Watershed Protection, 1998a). Planners have advocated open space development for many years for community design, preservation of rural character, or creation of affordable housing. However, it has only recently been identified as a site planning practice for reducing imperviousness and for environmental protection. Open space design is most effective for reducing impervious cover when used in conjunction with narrower streets and other alternative site design practices. Studies have shown that open space designs can reduce impervious cover from 15 to 50 percent when compared to conventional subdivision designs, particularly if narrow streets are utilized (NEMO, 1999). Open space designs can generally achieve significant reductions in impervious cover for most residential zones, although only minor reductions occur in areas with 1/8-acre lots and smaller (Center for Watershed Protection, 1998a).

The benefits of open space development are summarized in **Table 4-4**. In particular, this Manual encourages the use of open space development as an alternative to conventional subdivision layout to:

- *Reduce overall site imperviousness and associated stormwater impacts*
- *Avoid development in sensitive areas of a site*
- *Locate stormwater treatment facilities within the open space*

Historically, there have been several barriers to the widespread use of open space development in Connecticut, primarily due to poorly worded "cluster zoning" adopted by many communities in the 1960s and 1970s. Smaller lot sizes and compact development can be perceived as less marketable, and prospective homebuyers may have concerns over management of community open space. Other common obstacles have included opposition from adjacent residents due to concerns about density, traffic congestion, and property values. More recent studies have demonstrated that many of these concerns can be addressed through thoughtful site design and clear local ordinances (Center for Watershed Protection, 1998a). Conservation subdivisions have also been shown to have marketing and sales advantages, as buyers prefer lots close to or facing protected open space. Conservation subdivisions have also been shown to appreciate faster than counterparts in conventional developments (NEMO, 1999). The Jordan Cove Urban Watershed Monitoring Project in Waterford, Connecticut is expected to provide additional insight into the benefits of open space development. Recommended sources of additional information on open space and conservation development are listed at the end of this chapter.

Reducing Building Setbacks

Reducing building setbacks can reduce impervious cover. Reducing front yard setbacks results in shorter driveways. Narrower side yard setbacks may result in narrower lots and shorter road lengths, provided that narrower lots do not result in greater overall density of development. Flexible setbacks and frontage

Table 4-4 Benefits of Open Space Development

Benefit	
Reduction of site imperviousness	Reduces the cost of future public services needed by the development
Reduction of stormwater runoff and pollutant loads	Can increase future residential property values
Reduction of pressure to encroach on resource and buffer areas	Reduces the size and cost of stormwater quantity and quality controls
Reduction of soil erosion potential due to reduced site clearing	Concentrates runoff where it can be most effectively treated
Reserves large portion of site as green space	Provides a wider range of feasible sites to locate stormwater quality controls
Reserves portion of site in open space dedicated to passive recreation	Provides wildlife habitat
Reduces capital cost of development	Increases sense of community and pedestrian movement
Provides compensation for lots that may be lost when land is reserved for resource protection and stream buffers	Can support other community planning objectives such as farmland preservation, community preservation, and affordable housing

Source: Adapted from Schueler, 1995.

requirements have been shown to provide attractive and unique residential subdivisions (Center for Watershed Protection, 1998a). Despite these benefits, the use of flexible setback and frontage distances for reduction in impervious cover has not been widespread. Setbacks and frontage requirements are dictated by local ordinances to satisfy various community goals including uniformity of lot size, safety, and traffic congestion. As a result, concerns regarding parking, safety issues, subsurface sewage disposal systems, livability, and marketability are often impediments to relaxed setbacks and frontage widths. Reducing building setbacks is most readily accomplished along low-traffic streets where traffic congestion and noise are not a problem (Pennsylvania Association of Conservation Districts et al., 1998).

Limiting Sidewalks to One Side of the Street

Subdivision codes often require sidewalks on both sides of the street, as well as a minimum sidewalk width and distance from the street. Limiting sidewalks to one side of the street can reduce total site imperviousness. A sidewalk on one side of the street may suffice in low traffic areas where safety and pedestrian access would not be significantly affected. Sidewalk plans, similar to roadway plans, should be developed by towns to ensure that sidewalks move people efficiently from their homes to services and attractions (NEMO, 1999a). Reducing sidewalk widths, separating them from the street with a vegetated area, and grading sidewalks away from rather than towards the street can reduce impervious area and stormwater runoff.

Reducing Hydraulic Connectivity of Impervious Surfaces

Impervious surfaces that are not directly connected to the drainage collection system contribute less runoff and smaller pollutant loads than hydraulically connected impervious surfaces. Isolating impervious surfaces also promotes infiltration and filtration of stormwater runoff. Strategies for accomplishing this include:

- *Disconnecting roof drains and directing flows to vegetated areas or infiltration structures (swales, trenches, or drywells)*
- *Directing flows from paved areas such as driveways to stabilized vegetated areas*
- *Breaking up flow directions from large paved surfaces*
- *Encouraging sheet flow through vegetated areas*
- *Locating impervious areas so they drain to natural systems, vegetated buffers, natural resource areas, on-lot bioretention areas, or permeable soils*

(Prince George's County, Maryland, 1999).

Modifying/Increasing Runoff Travel Time

The peak discharge rate and volume of stormwater runoff from a site are influenced by the runoff travel time and hydrologic conditions of the site. Runoff travel time can be expressed in terms of "time of concentration" which is the time required for water to flow from the most distant point to the downstream outlet of a site. Runoff flow paths, ground surface slope and roughness, and channel characteristics affect the time of concentration. Site design techniques that can modify or increase the runoff travel time and time of concentration include:

- *Maximizing overland sheet flow*
- *Increasing and lengthening drainage flow paths*
- *Lengthening and flattening site and lot slopes (although may conflict with goal of minimizing grading and disturbance)*
- *Maximizing use of vegetated swales*

(Prince George's County, Maryland, 1999).

4.4 Low Impact Development Management Practices

Low Impact Development (LID), a relatively new concept in stormwater management pioneered by Prince George's County, Maryland and several other areas of the country, is a site design strategy that employs many of the concepts and practices already described in this chapter. The goal of LID is to maintain or replicate predevelopment hydrology through the use of small-scale controls integrated throughout the site (U.S. EPA, 2000). Site design techniques such as those described above are one component of the LID approach. The other major component of the LID approach is the use of micro-scale integrated management practices to manage runoff as close to its source as possible. This involves strategic placement of lot-level controls to reduce runoff volume and pollutant loads through infiltration, evapotranspiration, and reuse of stormwater runoff.

The appropriateness of LID practices is highly dependent on site conditions. Soil permeability, slope, and depth to water table and bedrock are physical constraints that may limit the use of LID practices at a site. Community perception and local development rules may also present obstacles to the implementation of LID practices, as described previously in this chapter. Although alternative site design and LID practices may not replace the need for conventional stormwater controls, the economical and environmental benefits of LID practices are well documented (U.S. EPA, 2000). LID practices described in the following sections include:

- *Vegetated Swales, Buffers, and Filter Strips*
- *Bioretention/Rain Gardens*
- *Dry Wells/Leaching Trenches*
- *Rainwater Harvesting*
- *Vegetated Roof Covers (Green Roofs)*

The main feature that distinguishes these practices from conventional structural stormwater controls is scale. These small systems are typically designed as off-line systems that accept runoff from a single residential lot or portions of a lot, as opposed to large multiple-lot or end-of-pipe controls. The following sections contain summary descriptions of these small-scale LID practices. The design sections of this Manual contain more detailed guidance for similar, larger-scale stormwater treatment practices such as bioretention, infiltration, and filtration systems.

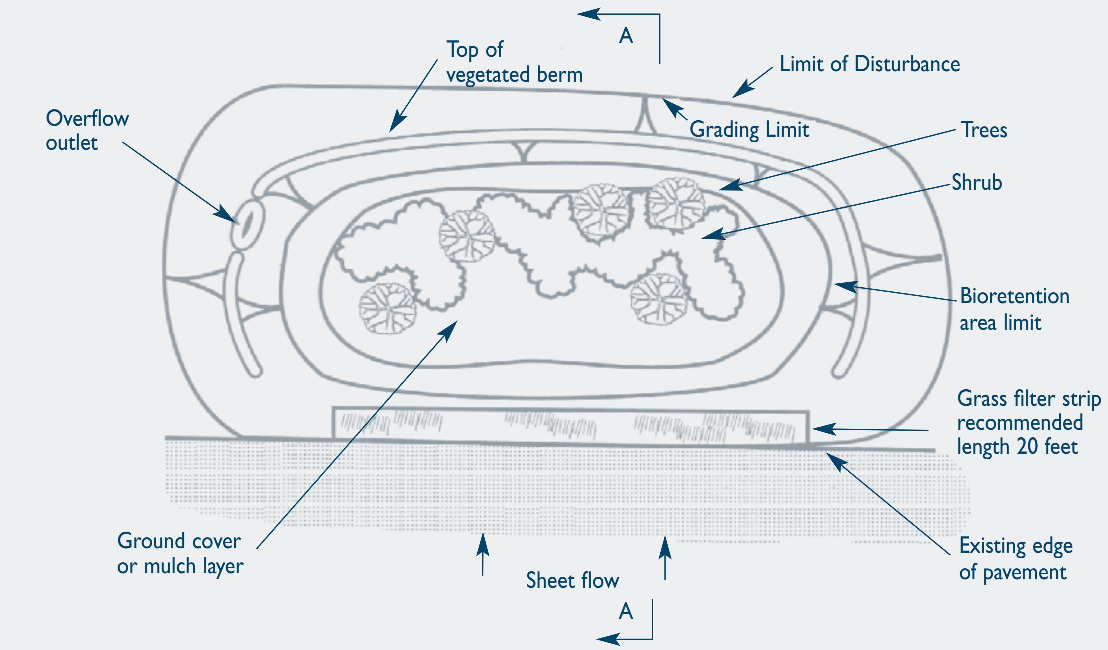
4.4.1 Vegetated Swales, Buffers, and Filter Strips

Vegetated swales, buffers, and filter strips are vegetative practices that can be incorporated into a site to maintain predevelopment hydrology. These practices are adaptable to a variety of site conditions, are flexible in design and layout, and are relatively inexpensive (U.S. EPA, 2000). Vegetated swales can provide both water quantity and quality control by facilitating stormwater infiltration, filtration, and adsorption. Vegetated buffers are strips of vegetation (natural or planted) around sensitive areas such as wetlands, watercourses, or highly erodible soils (Prince George's County, Maryland, 1999). Similarly, filter strips are typically grass or close-growing vegetation planted between pollutant source areas and downstream receiving waters or wetlands. Filter strips are commonly located downgradient of stormwater outfalls and level spreaders to reduce flow velocities and promote infiltration/filtration. Chapter Eleven provides additional design guidance on these vegetative practices.

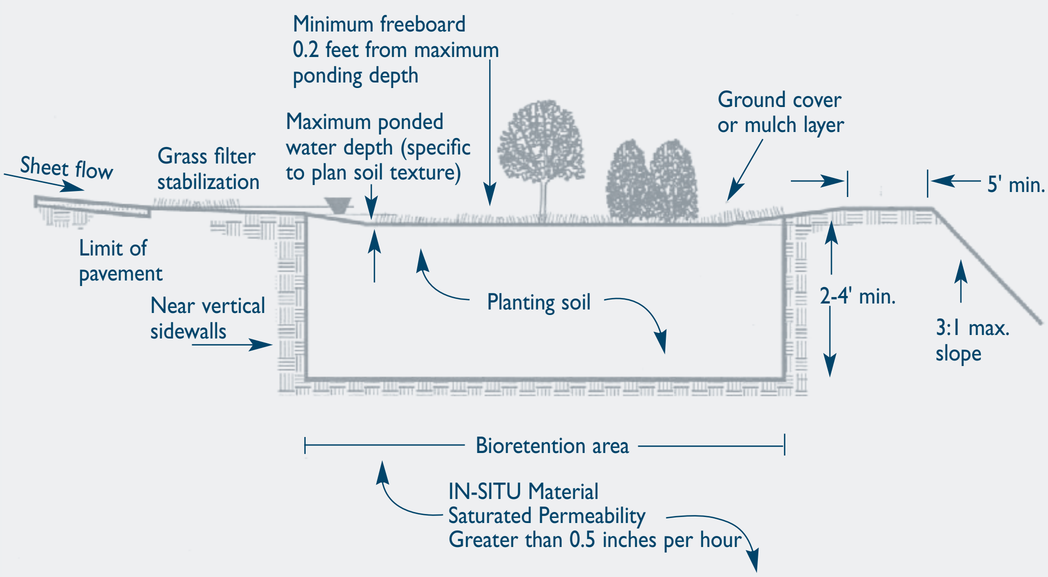
4.4.2 Bioretention/Rain Gardens

Bioretention is a practice to manage and treat stormwater runoff by using a specially designed planting soil bed and planting materials to filter runoff stored in a shallow depression (Prince George's County, Maryland, 1999). Bioretention areas are composed of a mix of functional elements, each designed to perform different functions in the removal of pollutants and attenuation of stormwater runoff. Bioretention removes stormwater pollutants through physical and biological processes, including adsorption, filtration, plant uptake, microbial activity, decomposition, sedimentation, and volatilization (U.S. EPA, 2000). The major components of a bioretention system include:

Figure 4-5 Functional Elements of a Bioretention Facility



Plan view (not to scale)



Section A-A (not to scale)

Source: Prince George's County, Maryland, 1999.

- *Pretreatment area (optional)*
- *Ponding area*
- *Ground cover layer*
- *Planting soil*
- *In-situ soil*
- *Plant material*
- *Inlet and outlet controls*

Figure 4-5 is a schematic of a typical bioretention facility depicting each of these functional elements. Bioretention facilities are most effective if they receive runoff as close as possible to the source and are incorporated throughout the site (Pennsylvania Association of Conservation Districts et al., 1998).

Rain gardens are a small-scale form of bioretention that can be incorporated into a variety of areas in new and existing developments, including:

- *Residential yards*
- *Street median strips*
- *Road shoulder rights-of-way*
- *Parking lot islands*
- *Under roof downspouts*

Rain gardens serve as a functional landscape element, combining shrubs, grasses, and flowering perennials in depressions that allow water to pool for only a few days after a rain (Metropolitan Council, 2001). The soil absorbs and stores the rainwater and nourishes the garden vegetation. Rain gardens are an effective, low-cost method for reducing runoff volume, recharging groundwater, and removing pollutants. **Figure 4-6** shows examples of several rain garden designs for residential lots.

4.4.3 Dry Wells/Leaching Trenches

Dry wells are small excavated pits or trenches filled with aggregate which receive clean stormwater runoff primarily from building rooftops. Dry wells function as infiltration systems to reduce the quantity of runoff from a site. Dry wells treat stormwater runoff through soil infiltration, adsorption, trapping, filtering, and bacterial degradation (Prince George's County, Maryland, 1999). **Figure 4-7** shows a schematic of a typical dry well. The use of dry wells is applicable for small drainage areas with low sediment or pollutant loadings, and where soils are sufficiently permeable to allow reasonable rates of infiltration and the groundwater table is low enough to allow infiltration. Chapter Eleven contains additional design guidance for dry wells.

4.4.4 Rainwater Harvesting

Rain is a renewable resource and is abundant in Connecticut. Rainwater harvesting can be used to supply water for drinking, washing, irrigation, and landscaping. It generally involves five main components: catchment, conveyance, purification, storage, and distribution. Catchment areas are most commonly roofs, while conveyance is via gutters and roof leaders. Rainwater is stored in either rain barrels or cisterns (water tanks). Purification for reuses other than drinking and washing primarily involves directing the initial flow of runoff, which contains the highest levels of accumulated contaminants, away from the storage system. Finally, distribution is through garden hoses or typical plumbing, depending on the application.

For the purposes of this manual, rainwater harvesting can be used to retain a portion of stormwater runoff during rain events and release it during dry periods such that the total volume of runoff is reduced. However, there are additional benefits to harvesting rainwater. Rainwater is generally very soft compared to other sources, as it does not come in contact with soil, and therefore contains low levels of dissolved salts and minerals. This makes it preferable for irrigation, gardening, and landscaping. If used for drinking and washing, soft water is less taxing on plumbing and water tanks.

Rain barrels are designed to retain small volumes of runoff for reuse for gardening and landscaping. Rain barrels are applicable to residential, commercial, and industrial sites and can be incorporated into a site's landscaping plan. Multiple rain barrels can be used to retain larger volumes of runoff. The size of the rain barrel is a function of rooftop surface area and the design storm to be stored. For example, one 42-gallon rain barrel provides 0.5 inch of runoff storage for a rooftop area of approximately 133 square feet (Prince George's County, Maryland, 1999). **Figure 4-8** shows a typical rain barrel.

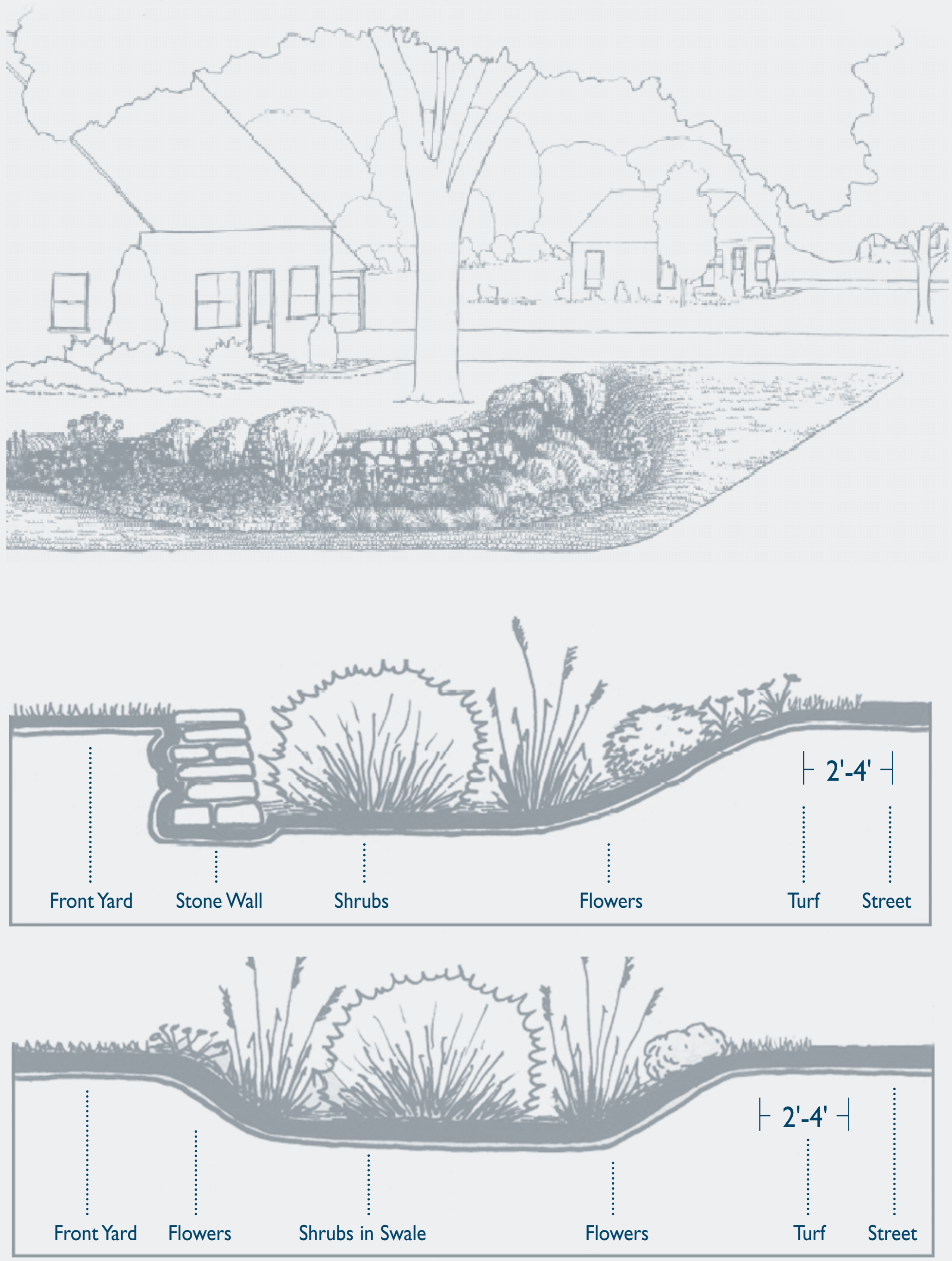
Cisterns store larger quantities of rooftop stormwater runoff and may be located above or below ground. Cisterns can also be used on residential, commercial, and industrial sites. Pre-manufactured cisterns come in a variety of sizes from 100 to 10,000 gallons. However, even larger concrete cisterns may be constructed in place for large industrial, commercial, and public uses. From a stormwater management perspective, the use of cisterns for commercial development where proposals include high levels of impervious cover, particularly in highly urbanized areas, should become a more commonly implemented stormwater management practice in the future.

General design considerations for rain barrels and cisterns include:

- *Equip rain barrels with a drain spigot with a garden hose threading*

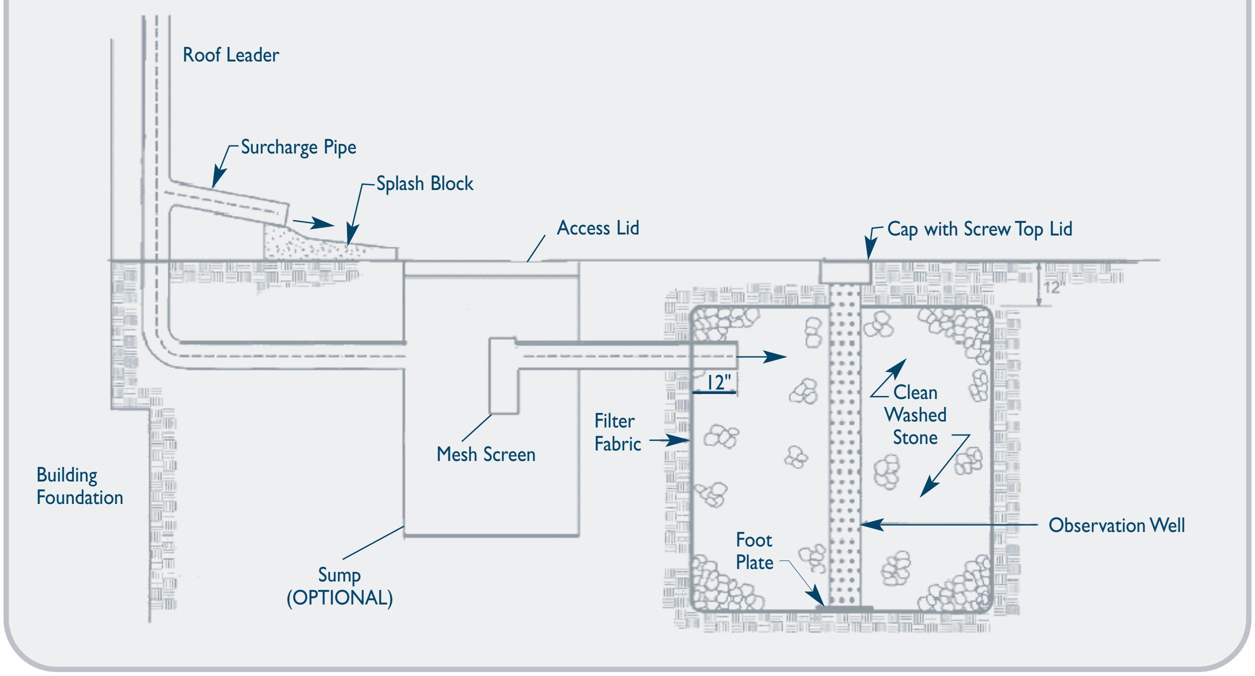
Figure 4-6 Residential Rain Gardens

Typical Residential Rain Garden (With and Without Masonry Wall)



Source: Metropolitan Council, 2001 (Adapted from Nassauer et al., 1997) and Low Impact Development Center (www.lowimpactdevelopment.org), 2001.

Figure 4-7 Schematic of Typical Dry Well



Source: Adapted from NYDEC, 2001.

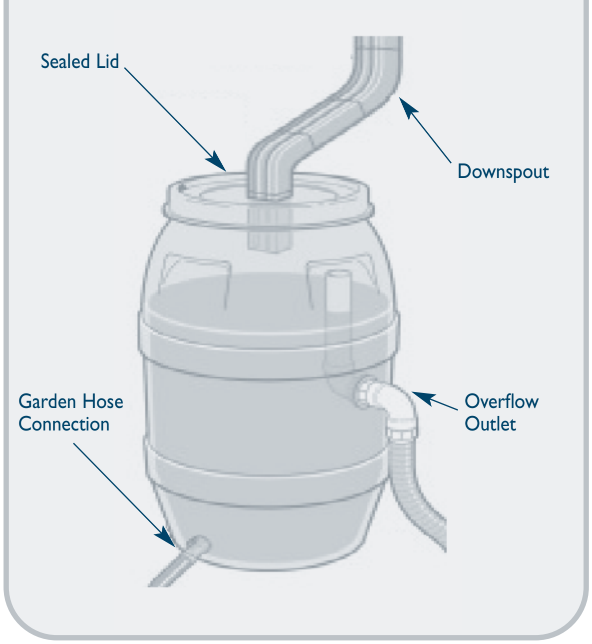
- *Use a tight-fitting, light-blocking lid to keep children and animals out of the water, stop the development of algae, and limit access to standing water by mosquitoes and other nuisance insects. Alternatively, a small mesh screen could be used over the hole in the barrel/cistern to limit mosquito-breeding potential*
- *Use a roof washer (collection and disposal of the first flush of water from a roof) to catch accumulated debris and divert the first flush of runoff away from rain barrels or cisterns*
- *Use an overflow device to direct excess water away from a building's foundation when the tank is full*
- *Monitor cistern intakes and overflows for blockage*
- *Locate cisterns as close to supply and demand as possible*
- *Size storage volume based on seasonal rainfall data and anticipated water requirements*
- *For drinking water supply, purification using ultraviolet light, ozonation, chlorination, reverse osmosis, and carbon filters can be used*

4.4.5 Vegetated Roof Covers

Vegetated roof covers, also referred to as "green roofs", are layers of vegetation installed on building rooftops. Green roofs are an effective means for reducing urban stormwater runoff by replacing impermeable rooftops with permeable, vegetated surfaces. Rainwater is either intercepted by vegetation and evaporated to the atmosphere or retained in the substrate before being returned to the atmosphere through transpiration and evaporation. Several examples of vegetated roof installations are shown in **Figure 4-9**.

The green roof is a multilayered, constructed roof system consisting of a vegetative layer, media, a geotextile layer, and a synthetic drain layer. Green roofs have been used extensively in Europe and are becoming more common in the United States. A variety of green roof designs exist. The simplest consists of a light system of drainage and filtering components and a thin soil layer, which is installed and planted with drought-resistant herbaceous vegetation (Metropolitan Council, 2001). This type of system is called an extensive system. More complex green roof systems such as roof gardens built to accommodate trees, shrubs, and recreational access are called intensive systems. **Figure 4-10** is a schematic of the functional components of the simpler extensive vegetated roof system.

Table 4-8 Typical Rain Barrel



Source: Adapted from urbangardencenter.com (D&P Industries, Inc., 2001).

Recently developed, modular green roof systems are available for new installations and building retrofits. These systems consist of interlocking modules containing plants that are shipped to the roof site for installation. The modules can be removed or replaced, thereby facilitating roof maintenance and repair.

Green roofs are effective in reducing total runoff volume. For example, simple vegetated roof covers with approximately 3 inches of substrate can reduce annual runoff by more than 50 percent in temperate climates (U.S. EPA, 2000). Green roofs not only retain rainwater, but also moderate the temperature of the water and act as natural filters for any of the water that happens to runoff (Green Roofs for Healthy Cities Website, 2001). Green roofs in urban areas offer a variety of other benefits such as:

- *Reduced energy costs by providing building insulation*
- *Conservation of land that would otherwise be required for stormwater controls*
- *Improvement of air quality by reducing carbon dioxide levels and binding airborne particulates*
- *Air temperature regulation and reduction of the "urban heat island" effect*
- *Sound insulation*
- *Improved aesthetics and views from other buildings*
- *Habitat for birds*

Design considerations for vegetated roof covers include structural and load-bearing capacity, plant selection, waterproofing and drainage, and water storage (Metropolitan Council, 2001). Limitations of green roof systems include:

- *Damage to waterproofing materials may result in serious roof damage*
- *Can be expensive to design and construct*
- *Sloped-roof applications require additional erosion control measures*
- *Higher maintenance than conventional roof*

Additional Information Sources

The UConn Cooperative Extension System's Nonpoint Education for Municipal Officials (NEMO) Project. In collaboration with DEP's NPS Program, the NEMO Project provides NPS management education and technical assistance to Connecticut municipalities free of charge. NEMO's goal is to help municipalities reduce NPS pollution by understanding natural resource based planning and how to implement it (http://www.nemo.uconn.edu).

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Figure 4-9 Examples of Vegetated Roof Installations

Source: Chicago City Hall (Roofscapes, Inc. 2001)

Source: Mashantucket Pequot Museum and Research Center, Mashantucket, Connecticut (Photo courtesy of American Hydrotech, Inc. 1998)

Source: Fencing Academy of Philadelphia (Charlie Miller, Roofscapes, Inc. 1998)

Source: Nonpoint Education for Municipal Officials (NEMO)

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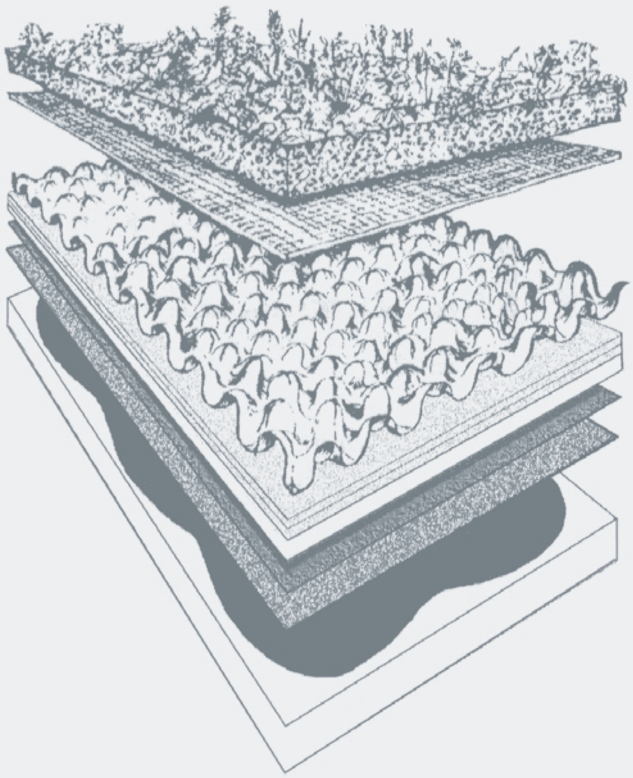
Figure 4-10 Schematic of a Typical Vegetated Roof System



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Chapter 5
Source Control Practices and Pollution Prevention

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Developing awareness of potential sources of pollution and ways to modify behavior in order to reduce both the amount of available pollutant and the volume of stormwater runoff are key elements in this approach to stormwater management. This chapter discusses the following source control and pollution prevention practices that are commonly applied in municipal, industrial, commercial and residential settings:

5.1 Introduction

Controlling the sources of pollution and preventing pollutant exposure to stormwater are important management techniques that can reduce the amount of pollutants in stormwater and the need for stormwater treatment. Source control practices and pollution prevention can include a wide variety of management techniques that address stormwater and other nonpoint sources of pollution. Most are typically non-structural, require minimal or no land area, and can be implemented with moderate cost and effort as compared to structural treatment practices. In addition to management actions, source control and pollution prevention also include education and outreach.

- *Street and Parking Lot Sweeping*
- *Roadway Deicing/Salt Storage*
- *Storm Drainage System Maintenance*
- *Other Road, Highway, and Bridge Maintenance*
- *Illicit Discharge Detection and Elimination*
- *Commercial and Industrial Pollution Prevention Plans*
- *Animal Waste Management*
- *Lawn Care and Landscaping Practices*
- *Model Stormwater Ordinances*
- *Public Education*

5.2 Municipal Practices

5.2.1 Street and Parking Lot Sweeping

Removal and proper disposal of sediment and debris from paved surfaces reduces the exposure of these materials to stormwater washoff and subsequent pollutant export to receiving waters. The reported effectiveness of street sweeping varies considerably among sources (e.g., EPA, 1983; Bannerman, 1999) and is particularly dependent upon the type of sweeper used.

Sweeper Type

Mechanical Broom Sweepers: These are the oldest and most common type of sweeper used for municipal roadway cleaning. They work like a broom and dustpan to pick of particles and only remove large debris. Mechanical broom sweepers are relatively ineffective at removing particles smaller than 60 microns. In addition, the broom action may actually break larger particles into smaller ones, which are more difficult to pick up (Schwarze Industries, Inc., 2001).

Vacuum Sweepers: Vacuum sweepers work in a manner comparable to household vacuum cleaners. Typically, a broom head pushes debris toward a suction inlet or vacuum. Traditional vacuum sweepers use a water-based dust suppression system, but still exhaust a high level of particulates into the atmosphere while in operation (Schwarze Industries, Inc., 2001).

Regenerative Air Sweepers: Regenerative air sweepers use a closed-loop, cyclonic effect to clean. Air is constantly recirculated or regenerated in the unit. It is blasted onto the pavement on one side of the sweeper head, picks up debris as it travels across the width of the head, and is suctioned up on the vacuum inlet on the other side of the sweeper head. Regenerative air sweepers use water for dust suppression and exhaust some particulates into the atmosphere during operation.

Dry Vacuum Sweepers: Unlike water-assisted vacuum sweepers, dry vacuum sweepers use a filtration system and require no water for dust suppression. Consequently, this type of sweeper can also be used in colder weather, since freezing conditions are not an issue for operation. The internal filtration system also results in less fine-grained particulate exhaust to the atmosphere compared to the mechanical sweepers discussed above.

Sweeper Effectiveness

The improvements in sweeper technology over the past 20 years have considerably improved the capability of sweepers to pick up the fine-grained sediment particles that carry a substantial portion of the stormwater pollutant load (EPA, 2002). A study by Terrene Institute in 1998 has shown that mechanical broom sweepers and water-assisted vacuum sweepers reduce nonpoint source pollution by 5-30 percent and nutrient content by 0-15 percent. However, dry vacuum sweepers are reported to reduce non-point source pollution by 35-80 percent and nutrients by 15-40 percent. Bannerman (1999) estimates that, depending upon sweeping frequency, dry vacuum sweepers could achieve a 50-80 percent overall reduction in the annual sediment load for a residential street.

The effectiveness of pavement sweeping in reducing nonpoint source pollution in a particular area is a function of several variables including:

Street Condition: Regular pavement repair and maintenance will encourage a smooth pavement condition and texture which will reduce the amount of particulates shaken from vehicles, increase the ease of street sweeping, and reduce the amount of particulates generated from the deteriorating street surface itself.

Geographic Location: The frequency of precipitation events capable of removing particulates from the paved surface will influence the effectiveness of a sweeping program.

Sweeper Operator's Skill: Optimum pollutant removal is a function of operator control over sweeper speed, brush adjustment and rotation rate, sweeping pattern, and maneuvering around parked vehicles.

Presence of Parked Vehicles: On-street parking of vehicles during sweeping reduces overall effectiveness.

Amount of Impervious Area Devoted to Rooftop (as compared to pavement): Sweeping is obviously more effective in areas where paved surfaces are the major contributor to impervious surfaces in a watershed.

Frequency of Sweeping: More frequent sweeping should improve overall sediment load reductions, and is particularly important for streets or other paved areas with high pollutant loadings.

Type of Mechanical Sweeper Used: As discussed above, dry vacuum and regenerative air sweepers are preferable to mechanical broom and traditional water-assisted vacuum sweepers. State, municipal, commercial, and industrial facilities with street sweepers should consider upgrading to the latest sweeping technology when new equipment is purchased. A 10-year equipment replacement cycle is recommended. (EPA, 2002). In colder climates such as Connecticut, street sweeping can be effectively used during the spring snowmelt to reduce pollutant loads from road salt (see section on deicing for further information) and sand export to receiving waters. In Connecticut, the recommended minimum frequency for street sweeping is once per year as soon as possible after snowmelt and, when possible, before spring rainfall events. In urbanized areas and other areas with higher potential pollutant loadings, streets may require sweeping more than once per year.

Because of the initial capital cost and operation and maintenance costs associated with a street sweeping program, municipalities should prioritize street sweeping activities to achieve the most effective pollution prevention. In general, street sweeping is most effective in urban areas and pollutant removal rates are typically higher on residential roads than for arterial roadways (EPA, 2002). When developing a street sweeping program, more sophisticated sweepers such as dry vacuum sweepers should be used in areas of higher pollutant loading, and these areas should also be considered for more frequent sweeping. Municipalities can also improve the effectiveness of street sweeping programs by enforcing construction site erosion controls, especially the use of anti-tracking pads to minimize excess sediment on paved surfaces; and developing and enforcing regulations for alternate side parking during cleaning operations, litter control, and trash and refuse storage and disposal, especially yard debris.

Disposal of Sweepings

Street sweepings may contain low levels of chemical compounds associated with stormwater runoff such as lead, sodium and compounds associated with asphalt and motor oils. Street sweepings are also likely to contain debris such as leaves, broken glass, and small pieces of metal.

Temporary Storage of Street Sweepings: Temporary storage of street sweepings prior to reuse or disposal should be located in an area where the sweepings will not wash into wetlands or watercourses. Acceptable temporary storage sites include:

- *an empty salt storage shed*
- *a municipal site where sand and salt are normally handled*
- *a paved area that is more than 100 feet from a wetland or watercourse*

Street sweepings should not be combined with sand and debris collected from catch basins. Material removed from catch basins may have higher concentrations of pollutants. Prior to reuse, materials such as trash, leaves and debris should be removed from the street sweepings by screening or other appropriate method and such materials should either be disposed of at a permitted solid waste facility, recycled (e.g. aluminum cans) or composted (e.g. leaves).

Limitations on Reuse of Street Sweepings without Testing: It is acceptable to reuse street sweepings without analyzing the concentration of chemical compounds in the following ways:

- *as fill in road construction projects where the sweepings are used below the paved surface or in the median strip of a divided highway*
- *as aggregate in concrete or asphalt*
- *as daily cover on a permitted landfill*

Limitations on Reuse of Street Sweepings with Testing: Properly tested street sweepings may be used for fill material on an industrial or commercial property, provided the testing for both heavy metals and semivolatile organic compounds, at a frequency of approximately one sample per 500 cubic yards of street sweepings, shows concentrations below the residential direct exposure standards established in the Remediation Standard Regulations found in Appendix A to Sections 22a-133k-1 through 22a-133k-3 in the Regulations of Connecticut State Agencies ("RCSA"). Alternatively, properly tested street sweepings may be reused at other sites in accordance with the regulations for reuse of polluted soil pursuant to Section 22a-133k-2(h) RCSA.

No Use on Residential Property: Street sweepings, regardless of testing status, are not recommended for use on residential property because they may contain broken glass or other sharp debris.

Disposal at Permitted Solid Waste Facility: Street sweepings that are not used in the manner described above should be disposed of at a permitted solid waste facility.

5.2.2 Roadway Deicing/Salt Storage

Salts, sand, gravel and other materials are applied to roadways during the winter months in Connecticut. The salts and other deicing materials discussed below lower the melting point of ice and are applied to reduce icing on roadways. Sand and gravel are applied to roadways to increase traction during and after adverse winter weather conditions.

Common Deicers

Sodium Chloride: Also called rock salt, this is the most commonly used deicing product due to its low cost and effectiveness. Sodium chloride will work at temperatures as low as –7°F, but is most effective at 10-15°F.

Calcium Chloride: This salt is a more expensive deicing agent than sodium chloride. However, it works at temperatures as low as -60°F, but is most effective at approximately -25°F.

Calcium Magnesium Acetate (CMA): CMA is a frequently used alternative to sodium chloride. It is made from dolomitic limestone treated with acetic acid. It is reported to work at temperatures as low as -5°F, but is most effective at approximately 20-25°F (Ohrel, 2000).

Blended Products: These new deicing materials consist of various combinations of sodium, calcium, magnesium, and chloride, as well as other constituents, but typically are lower in sodium chloride (Lucas, 1994).

Environmental concerns related to roadway deicing materials include:

- *Damage to vegetation growing adjacent to roadways receiving salt application (See plant list in **Appendix A** for a list of more salt-resistant vegetation for roadway plantings)*
- *Residues of chloride ions on the roadway surface that may contaminate groundwater resources*
- *Other substances in deicing chemicals that act to prevent caking (i.e., sodium ferrocyanide) or prevent corrosion may be toxic to human, animal, and fish life (FWHA, 1999)*

Table 5-1 compares the environmental effects of several common roadway deicers as reported in a 1993 study by the Michigan Department of Transportation and cited by Ohrel (2000). Other potential environmental impacts associated specifically with sodium chloride include temporary reductions in soil microbes, sensitivity of certain deciduous trees, and secondary components (3-5 percent of road salt composition)

Table 5-1 Comparison of Environmental Effects of Common Roadway Deicers

Media	Sodium Chloride (NaCl)	Calicum Chloride ($CaCl_2$)	CMA ($CaMgC_2H_3O_2$)	Sand (SiO_2)
Soils	Cl complexes release heavy metals; Na can break down soil structure and decrease permeability	Ca can exchange with heavy metals, increase soil aeration and permeability	Ca and Mg can exchange with heavy metals	Gradually will accumulate on soil
Vegetation	Salt spray/splash can cause leaf scorch and browning or dieback of new plant growth up to 50 feet from road; osmotic stress can result from salt uptake; grass more tolerant than trees and woody plants		Little effect	Accumulates on and around low vegetation
Groundwater	Mobile Na and Cl ions readily reach groundwater, and concentration levels can increase in areas of low flow temporarily during spring thaws. Ca and Mg can release heavy metals from soil			No known effect
Surface Water	Can cause density stratification in small lakes having closed basins, potentially leading to anoxia in lake bottoms; often contain nitrogen, phosphorus, and trace metals as impurities, often in concentrations greater than 5 ppm		Depletes dissolved oxygen in small lakes and streams when degrading	No known effect
Aquatic Biota	Little effect in large or flowing bodies at current road salting amounts; small streams that are end points for runoff can receive harmful concentrations of Cl; Cl from NaCl generally not toxic until it reaches levels of 1,000-36,000 ppm.		Can cause oxygen depletion	Particles to stream bottoms degrade habitat

Source: Adapted from Ohrel, 2000.

including nitrogen, phosphorus, and metals that may be released to receiving waters (Ohrel, 2000). The Federal Highway Administration (FHWA, 1999) reports that surface water resources are not as susceptible as groundwater to impacts from deicing chemicals due to the blending and dilution of runoff entering surface waters. However, the impact to surface waters depends on the amount of deicing chemical applied, the intensity of subsequent precipitation events, and the ecological health and use of the receiving water (FHWA, 1999).

Storage

Proper placement and storage of deicing chemicals is also important for preventing contamination of surface water runoff. **Table 5-2** summarizes recommendations for minimizing environmental impacts related to deicer, particularly salt, storage. Storage facilities should not be located within 250 feet of a well utilized for public drinking water, within a mapped Level A aquifer protection area, or within a mapped 100-year floodplain. They should also be at least 100 feet from wetlands or watercourses. Storage piles should be covered. This reduces the loss of deicing compounds from stormwater runoff and subsequent contamination of surface waters. Operationally, this reduces caking and clumping, making it easier to load and apply (EPA, 2002). Ideally, a structure should be provided for storage. At a minimum, all stockpiles should be covered with an appropriately sized, weighted tarp. All stockpile storage should be on impermeable pads.

Application

Proper application of deicers is important for both traffic safety and to prevent increased concentrations in roadway runoff. **Table 5-2** summarizes a few key suggestions for minimizing environmental impacts related to deicer, particularly salt, application. The Connecticut Department of Transportation (DOT) has developed guidelines for mixtures and application rates of sodium chloride and sand on state-maintained roadways in Connecticut (DOT, 1999). The mixture and application rates are a function of the type of roadway (i.e., two-lane versus multi-lane) and the weather and roadway conditions. Connecticut DOT also uses roadway sensors on some roads to create a thermal mapping of roadway temperatures and truck-mounted sensors that read both ambient and pavement temperatures. Since there may be differences between air and pavement surface temperatures, the use of sensors allows Connecticut DOT to tailor application rates to roadway conditions.

Training of public works personnel or others responsible for deicing in the proper storage and most effective application of deicers is also an important pollution prevention technique. The Salt Institute has developed a "Sensible Salting" training program (The Salt Institute, 2002) that focuses on maximizing the deicing properties of sodium chloride for roadway safety while protecting the environment. The program addresses:

- *Personnel training*
- *Equipment*
- *Calibration of spreaders*
- *Use of automatic controls*
- *Adequate, covered storage*
- *Proper maintenance around storage areas*
- *Environmental awareness for salt applicators*

Public drinking water supplies (potable surface water and groundwater) are particularly susceptible to contamination from roadway deicers. Reduced application rates or alternative deicers (calcium chloride or CMA) are recommended in environmentally sensitive areas such as public water supply watersheds, aquifer protection areas, and areas of high groundwater recharge. Road crews should be familiar with identified sensitive areas that may be affected by roadway deicer application.

Snow Disposal

"Waste" snow accumulated from plowing activities can be a source of contaminants and sediment to surface waters if not properly located. DEP has developed guidance for the disposal of post-plowing snow (DEP, 1995). The "waste" snow piles should be located in upland areas only and should not be located in the following locations:

- *Storm drainage catch basins*
- *Storm drainage swales*
- *Stream or river banks that slope toward the water*
- *Freshwater or tidal wetlands or immediately adjacent areas*

Table 5-2 Recommendations to Reduce Deicer Impacts

Activity	Recommendations
Storage	❍ Salt storage piles should be completely covered, ideally by a roof and, at a minimum, by a weighted tarp, and stored on impervious surfaces ❍ Runoff should be contained in appropriate areas ❍ Spills should be cleaned up after loading operations. The material may be directed to a sand pile or returned to salt piles ❍ Avoid storage in drinking water supply areas, water supply aquifer recharge areas, and public wellhead protection areas
Application	❍ Application rate should be tailored to road conditions (i.e., high versus low volume roads) ❍ Trucks should be equipped with sensors that automatically control the deicer spread rate ❍ Drivers and handlers of salt and other deicers should receive training to improve efficiency, reduce losses, and raise awareness of environmental impacts
Other	❍ Identify ecosystems such as wetlands that may be sensitive to salt ❍ Use calcium chloride and CMA in sensitive ecosystem areas ❍ To avoid over-application and excessive expense, choose deicing agents that perform most efficiently according to pavement temperature ❍ Monitor the deicer market for new products and technology

Source: Adapted from Ohrel, 2000.

- *Within 100 feet of private drinking water supply wells*
- *Within 500 feet of public drinking water supply wells*
- *Public drinking water supply watershed areas*

5.2.3 Storm Drainage System Maintenance

In order to maintain their intended function, stormwater drainage and treatment systems should be inspected at least annually. Deterioration of any part of the system that threatens the structural integrity of the facility should be immediately repaired. Inspection and cleaning of catch basins and stormwater inlets preserves the sediment-trapping function of these devices and also prevents sediment, trash, and other pollutants present in the storm drain system from reaching receiving waters. Removal of sediment and decaying debris from catch basin sumps yields aesthetic and water quality benefits including reduction of foul odors, suspended solids, bacteria, and the load of oxygen demanding substances (EPA, 1999; EPA, 2002). Pitt (1979, 1984) found that cleaning catch basins in urban areas twice a year reduced the loads of total solids and lead in urban runoff by 10 percent and 25 percent, respectively. This maintenance schedule also reduced loads of chemical oxygen demand (COD), total Kjeldahl nitrogen, total phosphorus, and zinc by 5 percent to 10 percent (Wisconsin Department of Natural Resources, 1994).

Catch basins and other stormwater structures that accumulate sediment should be cleaned at least annually. The cleaning should include both removal of sediment from the sump and removal of any trash or debris from the grate. Additional maintenance is recommended in the fall to remove trash, leaves, and other debris. In rural areas and areas that experience significant accumulation of leaves, the recommended fall maintenance should be performed after leaf fall and before the first snowfall. In addition, areas with higher pollutant loadings or discharging to sensitive water bodies should also be cleaned more frequently (WEF and ASCE, 1998). More frequent cleaning of drainage systems may also be needed in areas with relatively flat grades or low flows since they may rarely achieve sufficiently high flows for self-flushing (Ferguson et al., 1997). Deviations from these recommended frequencies may be warranted based on field evaluation of actual sediment and debris accumulation rates, including identification and prioritization of structures that may require more or less frequent cleaning.

In addition to catch basin cleaning, storm drainage system maintenance should include removal of debris from surface basins used for stormwater management (Washington, 2000). The design sections of this Manual contain additional guidance on maintenance of stormwater treatment practices.

Polluted water or sediment removed from the storm drainage system must be disposed of properly. Before disposal, a detailed chemical analysis of the material should be performed to determine proper methods for storage and disposal (EPA, 1999).

Stormwater drainage systems located on private property, but subject to regulatory review and permitting, should be required to have similar operation and maintenance plans to protect receiving waters.

5.2.4 Other Road, Highway, and Bridge Maintenance

The following operation and maintenance practices for roads, highways, and bridges can further reduce stormwater pollutant loadings:

- *Develop an overall inspection program to ensure that general maintenance is performed on urban runoff and nonpoint source pollution control facilities.*
- *The use of chemicals such as soil stabilizers, dust palliatives, sterilants, and growth inhibitors should be limited to the best estimate of optimum application rates. All feasible measures should be taken to avoid excess application and consequent intrusion of such chemicals into surface runoff.*
- *Use techniques such as suspended tarps, vacuums, or booms to reduce, to the extent practicable, the delivery to surface waters of pollutants used or generated during bridge maintenance (e.g., paint, solvents, scrapings).*
- *Maintain retaining walls and pavements to minimize cracks and leakage.*
- *Repair potholes.*
- *Inspect silt fences and replace deteriorated fabrics and wire connections. Properly dispose of deteriorated materials.*
- *Renew riprap areas and reapply supplemental rock as necessary.*
- *Repair/replace check dams and brush barriers; replace or stabilize straw bales as needed.*
- *Regrade and shape berms and drainage ditches to ensure that runoff is properly channeled.*
- *Seed and fertilize, seed and mulch, and/or sod damaged vegetated areas and slopes.*
- *Apply seed and mulch where bare spots appear, and replace matting material if deteriorated.*
- *Ensure that culverts and inlets are protected from siltation.*

- *Inspect all permanent erosion and sediment controls on a scheduled, programmed basis.*
- *Ensure that energy dissipators and velocity controls to minimize runoff velocity and erosion are maintained.*

5.2.5 Illicit Discharge Detection and Elimination

Illicit discharges are non-stormwater flows that discharge into the stormwater drainage system. Failing septic systems, wastewater connections to the storm drain system, and illegal dumping are among the types of illicit discharges that can occur. Depending on the source, an illicit discharge may contain a variety of pollutants that can impact both human health and the aquatic environment. Identifying and eliminating these discharges is an important means of pollution source control in a stormwater drainage system.

This section provides a brief description of several common types of illicit discharges, techniques for illicit discharge detection, and public education and regulatory measures for preventing illicit discharges.

Failing Septic Systems

Septic systems are on-site wastewater disposal systems that provide a means of treating domestic wastewater in areas where public sanitary sewers are not available. After separating the solids from the wastewater stream, the septic system discharges the effluent into the ground. A failing septic system discharges effluent into the ground at concentrations that exceed water quality standards. Systems can fail for a number of reasons including unsuitable soil conditions, lack of or improper maintenance, or improper design and installation (EPA, 2002). Failing systems, as well as properly functioning septic systems in some instances, can be significant sources of nutrients, especially nitrogen, and microbial pathogens to both surface water and groundwater. Effluent that pools on the ground surface can be transported by runoff and enter nearby storm drainage systems and surface waters.

Detection of individual failing septic systems typically requires detailed on-site inspection. However, the presence of odors and isolated areas of very green grass or pooling on the ground surface are typical indicators of a failing system. Detection of optical brighteners and the use of color infrared (CIR) aerial photography are two field screening techniques that can be used (EPA, 2002). Optical brighteners are fluorescent white dyes that are used as additives in laundry soaps and detergents and are commonly found in domestic wastewater. The presence of optical brighteners can be detected by placing cotton pads in storm drains, pipes, or surface waters and then exposing them to ultraviolet light (Sargent and Castonguay, 1998). CIR is a relatively quick and cost-effective method that uses variations in vegetation growth or stress patterns to determine potentially failing septic systems (EPA, 2002).

Prevention of discharges from failing septic systems relies heavily on public education to inform homeowners about the need for routine septic system maintenance. Local health departments have educational materials available to assist with public education on this issue. In some cases, municipalities have instituted local ordinances with advanced design standards, mandatory pump-out schedules, required reporting of pump-out activities by private vendors, and inspection of septic systems upon property transfer (EPA, 2002).

Wastewater Connections

Untreated wastewater (e.g., process wastewater, wash waters, and sanitary wastewater) from business or commercial establishments that is discharged to the storm drainage system can introduce heavy metals, oil and grease, solids, sewage, detergents, nutrients, ammonia, chlorine and potassium (EPA, 2002). These contaminants can result in a variety of impacts to human health and the aquatic environment, including eutrophication, aquatic toxicity, reduced oxygen levels, and bacterial contamination (EPA, 2001).

Illicit wastewater discharges may be the result of inadvertent cross-connections between sanitary sewer and storm drainage systems. Floor drains, wash sinks, sump pumps, and solvent sinks are examples of drains that may be inadvertently connected to the storm drainage system as the result of poor mapping on internal facility pumping systems or incorrect sewer mapping (EPA, 2002). In some cases, untreated wastewater may be intentionally discharged to the storm drainage system as an inexpensive or convenient alternative to proper wastewater disposal and treatment (EPA, 2002).

Detection of illicit discharges for commercial and industrial sites can occur during both the design phase and during facility operation. During construction, inspection and verification of facility piping can avoid the need for later detection and evaluation. For facilities in operation, the use of the field screening techniques, source testing protocols, and the visual inspection methods described below can identify improper connections.

Illegal Dumping

The disposal of solid wastes in an unpermitted area, the pouring of liquid wastes or placement of trash into a storm drainage system, and blowing or sweeping of landscape debris into a public right of way or a storm drainage system are common methods of illegal dumping. Runoff from areas of illegal solid waste disposal can enter the stormwater drainage system and pollute receiving waters. Liquids or solids deposited directly into the storm drainage system are also sources of potential contamination. The extent and type of pollution generated by illegal dumping and the subsequent water quality impairment depends upon the characteristics of the illicit discharge.

Most municipalities have ordinances that prohibit illegal dumping and include penalties such as fines, jail time, or community service. However, detection of illegal dumping activities requires public education and awareness to encourage reporting of suspected illegal dumping activities.

Methods of Illicit Discharge Identification

Methods for identifying illicit discharges can vary widely in the level of effort and cost required for implementation. The following field-based methods are often used to identify illicit discharges in storm drainage systems:

Testing of Dry Weather Discharges: Flows from stormwater outfalls during dry weather may indicate an illicit discharge. A combination of visual inspection and chemical analysis of dry weather discharges can aid in identifying potential discharge sources.

Visual Inspection: Examination of piping connections by either physical examination or closed-circuit camera can be used to identify possible illicit connections.

Review of Piping Schematics: Examination of architectural plans and plumbing details can reveal potential sites of improper connections.

Smoke Testing: Injection of a non-toxic vapor (smoke) into the facility plumbing system and following its path of travel can be used to locate connections.

Dye Testing: In this method, appropriate colored dyes are added into the drain water of suspect piping. Appearance of the dyed water in the storm drainage system indicates an illicit discharge. As mentioned in the discussion of septic system discharges, testing for optical brighteners can provide an indication of the presence of domestic wastewater flows.

Infrared, Aerial, and Thermal Photography: Use of aerial, infrared, and thermal photography to locate patterns of stream temperature, land surface moisture, and vegetative growth are emerging techniques to identify potential illicit discharges to stormwater systems.

(EPA, 1999; 2002). In addition to these field methods, building and plumbing codes can help to prevent potential cross-connections between storm drainage and sanitary sewer systems. Municipalities can also prioritize illicit discharge detection efforts based on building age and/or operation type. Older buildings are more likely to have cross connections or other inappropriate discharges. A possible priority system for detecting illicit discharges from businesses is as follows:

1. *Automobile-relatedbusinesses/facilities and heavy manufacturing*
2. *Printers, dry cleaners/laundries, photo processors, utilities, paint stores, chemical laboratories, construction companies, and medium to light manufacturing*
3. *Institutional facilities, private service agencies, retail establishments, and schools*

(EPA, 2002).

5.3 Industrial and Commercial Practices

5.3.1 Stormwater Pollution Prevention Plans

Commercial and industrial facilities, including institutional facilities, can potentially contribute point or nonpoint pollution to stormwater through activities associated with operations, maintenance, and storage. DEP provides general pollution prevention information applicable to a wide variety of industries as well as pollution prevention fact sheets for the following specific industries:

- *Aerospace*
- *Chemical Manufacturers*
- *Coating*
- *Dry Cleaning Businesses*
- *Fabricated Metal*
- *Fiberglass-Reinforced Composite Plastics*
- *Marine Maintenance and Repair*
- *Metal Casting*
- *Metal Manufacturing/Finishing*
- *Metal Parts Cleaning*
- *Paint Manufacturers*
- *Pesticide Applicators*
- *Pesticide Formulating*
- *Pharmaceutical*
- *Photoprocessing*
- *Radiator Service*
- *Printed Circuit Board*
- *Printing*
- *Research and Educational Institutions*
- *Steel*

(DEP, 2002). Stormwater Pollution Prevention Plans (SWPPPs) are one facet of a facility-wide approach to pollution prevention activities. SWPPPs identify potential sources of pollution and outline specific management activities designed to minimize the introduction of pollutants into stormwater. In Connecticut, commercial and industrial facilities required to register under the General Permit for the Discharge of Stormwater Associated with Commercial Activities or the General Permit for the Discharge of Stormwater Associated with Industrial Activities have specific SWPPP requirements. (See Chapter One for a discussion of stormwater regulatory programs) Although each SWPPP must be tailored to an individual facility, as well as any regulatory requirements, the following elements are typically included:

Description of Potential Pollutant Sources: This section of the plan describes potential sources of pollutants that may reasonably be expected to affect stormwater quality at the site or that may result in the discharge of pollutants from the site during dry weather. Activities (e.g., fueling, vehicle and equipment maintenance and cleaning, and loading and unloading) and materials that may be sources of stormwater pollution should be identified. This section of the SWPPP may also include a description of the site drainage showing the direction of stormwater flow, an inventory of materials exposed to precipitation, a list of spills and leaks, and a description of any monitoring done at the site.

Stormwater Management Measures and Controls: This section of the plan describes stormwater management measures and controls for the facility and a schedule for their implementation. Typical elements discussed in this section of the SWPPP include good housekeeping practices, vehicle or equipment washing, sediment and erosion control, preventive maintenance, sweeping, spill prevention and response, outside storage, employee training, non-stormwater discharges, facility inspection, and stormwater runoff management and treatment.

Comprehensive Site Compliance Evaluation: A qualified individual knowledgeable about the General Permit requirements and the objectives and contents of the SWPPP should conduct an evaluation of the site for compliance with the provisions of the SWPPP on a regular basis. The frequency of the evaluation depends on specific permitting requirements, but typically is at least annually for commercial sites and twice per year for industrial facilities in Connecticut. The evaluation should include a visual inspection of potential pollutant sources identified in the plan to determine evidence of, or potential for, pollution entering the stormwater system; an evaluation of the management measures identified in the plan to assure that they are in place and operating correctly; and visual inspection of equipment (e.g., spill response equipment) needed to implement the plan. If possible, inspections should be conducted during rainfall events and a written report of the inspection and its findings should be prepared and retained with the SWPPP.

Pollution Prevention Team: A pollution prevention team, consisting of one or more individuals, should be identified in the plan. The team will be responsible for developing, implementing, maintaining, and revising the plan.

Record Keeping: Record keeping elements in the plan should include inspections and evaluations of the site, a list of the pollution prevention team members and their assigned responsibilities, spill control and response plans, training schedules, and stormwater-related maintenance schedules (e.g., structure cleaning, sweeping, etc.), as well as stormwater quality monitoring results.

Certification: If the SWPPP is a regulatory requirement, the plan will also require certification by a professional engineer, licensed to practice in Connecticut, stating that the SWPPP meets the requirements of the General Permit.

5.4 Lawn Care and Landscaping Practices

Source control and pollution prevention techniques related to landscaping and gardening activities rely on public education and awareness. The use of alternative landscaping techniques and judicious use of fertilizers and pesticides in landscaping and gardening require voluntary cooperation from the public, business owners, and landscaping professionals. While municipalities can establish landscaping practices for their public works or other departments that perform landscaping functions, public education is the primary method for encouraging private homeowners to adopt more environmentally friendly landscape and gardening practices. The UConn Cooperative Extension System's Residential Water Quality Program has educational workshops and materials to assist with this public education (http://www.nemo.uconn.edu).

5.4.1 Xeriscaping and General Landscape Management

Xeriscaping is landscaping to minimize water usage ("xeri" is the Greek prefix meaning "dry") and incorporates two essential components:

- *Using native plants that are adapted to Connecticut's climate and that require minimal watering, fertilizer, and pesticide application*
- *Improving soils by adding soil amendments or using mulches to reduce the need for watering by increasing the moisture retained in the soil*

(Salsedo and Crawford, 2000). In addition to promoting water conservation, minimizing water use and water loss will reduce the transport of pollutants into downstream surface waters. Because xeriscaping typically results in a reduced need for pesticides and fertilizers as part of landscape maintenance, this approach to lawn and turf management also reduces nutrient and pesticide contamination in stormwater runoff.

Residential and commercial property owners, as well as municipalities and other government agencies responsible for maintaining large vegetated areas, can use Xeriscaping. Xeriscaping incorporates seven basic principles that are also generally applicable to lawn and turf management:

Planning and Design: Appropriate and thoughtful planning and design is critical for the long-term success of the xeriscaped landscape. Landscape planning should consider soil and topographic characteristics, light conditions, drainage, existing plantings to be preserved, and owner preferences such as the desired level of maintenance, budget constraints and plant and color preferences (NYCDEP, 2002).

Soil Improvements: Improving soil conditions will help to retain water in the soil. Soil should be analyzed to determine current conditions and needed soil amendments. Addition of organic matter such as compost or peat moss to the soil will improve soil moisture retaining capabilities. The soil below the surface layer should be examined to identify limitations such as compaction.

Practical Turf Areas: Because of the water requirements of many turf grasses, limit or reduce the amount of turf areas (EPA, 2002), or convert existing turf areas to the alternatives described below. Groundcovers, planting beds or permeable surfaces like wood decks and brick-on-sand walkways are options for reducing turf areas (Salsedo and Crawford, 2000). Turf areas should be designed in rounded, compact shapes to water and mow more efficiently and appropriate turf varieties should be selected for the site. See the plant list in **Appendix A** for suggestions.

Appropriate Plant Selection: Selecting trees, shrubs, flowers, grasses, and groundcovers that are either native to the region or are non-invasive, non-native adapted species will reduce the amount of watering needed. These plants are adapted to the soil and rainfall conditions in Connecticut and in many cases will require minimal or no watering after an establishment period. Choosing a variety of plants will avoid a monoculture, which may be more susceptible to pest or insect problems than more stable and diverse plant populations (Greenbuilder, 2001). Native plants are also less susceptible to pests or disease (DEP, 1999b). In addition, it is advisable to select plants from reputable nurseries since these plants are often more viable. A partial list of native species is provided in **Appendix A**. For additional information on native species selection and availability, refer to the Additional Information Sources at the end of this chapter.

Efficient Irrigation: Irrigation techniques can be used to reduce overall water use. Encouraging the growth of deep roots enables plants to reach deeper into the soil for moisture. Watering only when needed and allowing the water to penetrate deeper into the soil will encourage deeper root growth (EPA, 2002). A soil moisture sensor can also be used to determine when watering is necessary. Using a soaker hose or drip irrigation system will target watering and result in less evaporation than occurs with sprinkler systems. Watering in the early morning and evening will also reduce evaporation losses. Collection of residential roof runoff in a rain barrel or cistern can provide a reservoir for landscape watering with high quality water (Salsedo and Crawford, 2000). In addition to these irrigation techniques, plants should also be grouped by water needs to reduce overall water usage.

Effective Use of Mulches: Use of mulch helps to maintain soil moisture, reduce weed growth, and prevent erosion (EPA, 2002). Organic mulches such as peat moss, compost, wood chips, shredded bark or bark nuggets, pine needles, cocoa bean shells, leaves, and sawdust retain soil moisture and provide nutrients to the soil for plant growth. Inorganic mulches such as sheeting, stone, or gravel will also reduce moisture loss, but will not provide nutrients and are recommended only for unplanted areas. Mulch typically should be placed in layers three to four inches thick and should be set back a few inches from shrub stems or tree trunks to avoid possible rodent damage to the bark.

Appropriate Regular Maintenance: Properly timed maintenance such as pruning, liming and fertilizing (only when indicated by soil testing), weeding, pest control and mowing will encourage the long-term viability of the xeriscaped landscape (NYCDEP, 2002). A composting area for yard and household waste will provide mulch and reduce solid waste disposal. Alternatively, designation of several smaller planting beds or areas in the landscape where grass clippings, pine needles or leaves can be recycled as mulch can decrease overall maintenance and create conveniently located supplies of organic mulch (Salsedo and Crawford, 2000). Mowing turf areas high and often lowers the stress on grasses and reduces watering needs. By setting mower blades at three inches and mowing when the lawn is at approximately four inches, clippings are less likely to mat and will provide nutrients for the lawn (DFWELE, 2001).

In addition to the xeriscaping concepts described above, no landscaping debris (grass clippings, leaves, brush, prunings, mulch, soil, etc.) should be deposited, dumped, blown, or swept directly into a watercourse, wetland, storm drainage system, or public right of way.

5.4.2 Fertilizer and Pesticide Management

Landscaping and gardening activities can result in contamination of stormwater through fertilizer and pesticide runoff. Over-application or mis-application of fertilizers can be a significant source of nutrients such as phosphorus and nitrogen in stormwater runoff. Pesticides in stormwater runoff may be toxic to aquatic organisms. The selection, rate, and timing of application of both fertilizers and pesticides are key for minimizing possible runoff contamination. These source control measures can be implemented by citizens, businesses, municipalities, and government agencies to minimize stormwater contamination.

Soil testing should be done prior to fertilizer application to ensure that appropriate fertilizers are selected and that the rate of fertilizer application is suitable for the soil conditions. Soil often contains adequate levels of phosphorous, and most fertilizer mixes contain significantly more phosphorous than necessary. Therefore, low-phosphorous fertilizers may be appropriate under most conditions. Phosphorous application is typically most critical when seeding. Slow-release organic fertilizers are recommended, as they are potentially less toxic than other types of commercial fertilizers and are less likely to enter stormwater runoff (EPA, 2002).

Fertilization should be timed so that it is most beneficial to the target species. For example, warm season grasses such as Creeping Red Fescue (Festuca rubra), Big Bluestem (Andropogon gerardii), or Little Bluestem (Schizachyrium scoparius) should be fertilized in small frequent doses in the summer while cool season grasses such as Kentucky bluegrass (Poa pratensis) benefit from fall fertilization (EPA, 2002). Research has shown that there is little or no benefit to applying fertilizers to turf after mid-September in Connecticut since nitrogen is leached into the soil with minimal or no benefit to the vegetation. In addition, to minimize mobilization of fertilizer into surface water runoff, fertilizer should not be applied on a windy day or immediately before a heavy rain.

Pesticides, which include herbicides, insecticides, fungicides, and rodenticides, should only be utilized when absolutely necessary and should be selected to specifically target the pests of concern. Potential pests, which may be weeds, diseases, insects, or rodents, should be positively identified in order to determine if they pose an actual threat to the landscape and to enable the targeted selection of pesticides. If possible, the use of chemical pesticides should be avoided. When chemical pesticide use is unavoidable, the least toxic pesticide that targets the pest of concern should be selected. This approach to pesticide usage is formalized in a management technique called Integrated Pest Management (IPM). IPM developed in the turfgrass management field to produce high quality ornamental turfgrass with the most judicious use of pesticides. The principals of IPM are applicable to any landscape. IPM combines monitoring, pest trapping, establishment of action thresholds, use of resistant varieties and cultivars, cultural, physical, and biological controls, and precise timing and application of pesticide treatments (DEP, 1999b).

As discussed in the section on xeriscaping, native plant species are typically better adapted to the local environment and require less fertilization and are less susceptible to pests and disease.

5.4.3 Animal Waste Management

The fecal matter of domestic pets and waterfowl can be carried by stormwater runoff into nearby waterbodies or storm drainage systems. In addition to contributing solids to stormwater, animal fecal matter is a source of nutrients and pathogens, such as bacteria and viruses, in stormwater runoff (EPA, 2002). Nutrients can contribute to eutrophication of waterbodies, which together with the oxygen consumption caused by decaying fecal matter, can encourage oxygen-depleting conditions in water bodies.

Recommended methods for proper disposal of domestic pet waste include:

- *Bagging the waste and disposing of it in household trash (EPA, 2002)*
- *Burying it in at least 5 inches of soil away from vegetable gardens and water supplies (University of Wisconsin – Extension, 1999)*

Source control and pollution prevention techniques for pet waste management rely on modification of the behavior of pet owners and typically involve the combined use of public education campaigns and local ordinances. Many people are not aware of the potential pollution caused by their pets. Information on both the pollution effects of pet waste and the proper methods for collection and disposal of the waste can be distributed to pet owners through direct mailings or municipal utility/tax bill enclosures, local veterinarians, local pet stores, and as part of a municipal dog or pet licensing process.

Creating an environment that encourages proper pet waste disposal in areas such as public parks where pet waste is likely to be found is an additional method of pollution prevention. Signage requesting that owners pick up and dispose of pet waste as well as the availability of plastic bags, scoops, and disposal receptacles are common techniques used. Local ordinances mandating pet waste removal and disposal are an additional tool. Such "pooper-scooper" laws typically require pet owners to remove and dispose of any waste generated by their pet at a location other than the owner's property and may include fines. In areas of sensitive water resources, such as bathing beaches, public water supplies or shellfish areas, prohibition of domestic pets is an additional source control mechanism.

In addition to domestic pets, waterfowl can be a significant source of nutrient and pathogen loading to surface waters. Canada geese are Connecticut's largest native waterfowl population and, along with gulls, are the primary sources of waterfowl-related water quality impacts. Since the 1950s, the "resident" population of Canada geese has grown dramatically. Unlike migrant populations that travel south in the winter, resident geese are well adapted to suburban habitat and live year-round in areas that provide a combination of open water, cover, and grazing areas. Park ponds, reservoirs, and golf courses are examples of areas that typically provide a combination of these habitat features. (DEP, 1999c).

Lethal methods of waterfowl control, such as hunting, are among the most effective, but are typically not feasible in the suburban and urban areas where waterfowl management is of greatest concern (DEP, 1999c). Other control methods for waterfowl, especially geese, consist of:

Habitat Modification: This method focuses on changes in the vegetation available for grazing and/or the alteration of the relationship between open water and grazing habitat. Geese are especially attracted to ponds and lakes that have gradually sloping banks and lawn or other similar vegetation, allowing them to easily walk between open water and land. Planting unpalatable species such as pachysandra or allowing vegetation to grow tall in areas adjacent to water bodies will make these areas unattractive for grazing. Planting of species that also create a visual and physical barrier (see below) between land and open water will also make the habitat less conducive to geese populations. In addition, it is important that people do not artificially feed geese (i.e., bread or grain), which can be a particularly prevalent problem in public parks.

Barriers and Exclusion: Barriers for goose control should be at least 3-feet high. Effective barriers can consist of either vegetation or structural materials. Dense shrub plantings or mixed-vegetation buffer zones 20 to 100-feet wide along a shoreline are possible vegetative barriers. Wooden snow fence, soft or hard nylon fencing, or chicken wire or weld wire fences are artificial barriers that can be effective, although not aesthetically pleasing, for excluding geese from freely crossing between open water and grazing areas (DEP, 1999c; Metropolitan Council, 2001).

Non-Toxic Repellants: Repellants that either change the reflective property of the grass and make it look unnatural to geese or irritate the throats of the geese can be sprayed on feeding areas.

Frightening Methods: In order to be effective, frightening methods need to be employed before geese establish a feeding pattern at a particular location because they may become accustomed to repetitious frightening methods once they realize that there is no real danger (DEP, 1999c). Typically, frightening methods are most effective when they coincide with feeding times, typically sunrise and sunset. Frightening techniques can consist of pyrotechnics that create loud noises. Visual methods such as helium balloons, flags, and scarecrows are often effective because geese are uncomfortable with moving objects overhead. Mylar plastic flash tape, strung like a string fence at one to two feet above the ground is another visual frightening method. Where feasible, free-ranging dogs trained to chase geese or even tethered dogs that are allowed extensive movement can be effective.

Mute swans are also an increasing problem in natural and constructed ponds/wetlands. These exotic birds are very territorial and chase away native waterfowl. In addition to increased loadings of fecal matter, these birds can damage planted and established vegetation and can uproot submerged plants. Mute swans have been identified as a significant cause of eelgrass bed decline in Long Island Sound.

5.5 Model Stormwater Ordinances

Municipal ordinances provide the legal authority for resource protection on the local level. Although ordinances need to be specific to the particular conditions of a community, stormwater-related ordinances typically contain the following basic elements:

Finding of Fact/Purpose and Objectives: This section addresses why the ordinance is necessary and what its objective and purpose is.

Authority/Jurisdiction: This section describes the authority for the adoption of the ordinance and the jurisdiction covered under the ordinance.

Definitions: Key terms used in the ordinance are clearly defined in this section.

Requirements and Standards: These elements may vary considerably depending upon the topic of the ordinance and the content of other ordinances already in place. These sections describe the actual elements of resource protection.

Enforcement: This section describes violations of the ordinance, notices of violations, and penalties.

Appeals and Variances: These sections describe the mechanism and requirements for appeals and variances under the ordinance.

(Wisconsin Department of Natural Resources, 1994; EPA, 2000). As described in prior sections of this chapter, municipal ordinances provide an enforceable method of instituting the following pollution prevention and source control measures:

Illicit Discharges: An illicit discharge ordinance regulates non-stormwater discharges to municipal stormwater drainage systems. A critical element of illicit discharge ordinances is a guaranteed "right of entry" to private property, giving the authority to inspect properties suspected of releasing contaminated discharges into the stormwater drainage system (CWP, 2002a). **Appendix C** contains a model illicit discharge detection and elimination ordinance developed by DEP in conjunction with the Stormwater Phase II Municipal Separate Storm Sewer System (MS4) General Permit.

Post-Construction Stormwater Controls: Ordinances for post-construction stormwater controls are useful for communities that have no existing ordinances addressing stormwater management. Typically a post-construction stormwater control ordinance will include language referring to the latest version of a stormwater guidance manual so that the ordinance itself will not need to be updated to reflect technological advances or changes in stormwater management techniques. The ordinance should also require a post-construction stormwater management plan, including plan contents and operation and maintenance requirements (CWP, 2002b).

To ensure that new and redevelopment projects include stormwater management plans, municipal planning and zoning commissions should review and revise their site and subdivision plan submission requirements to require such plans. Chapter Nine describes how to develop a site stormwater management plan.

Stormwater Operation and Maintenance: For communities with existing ordinances that address stormwater management, but do not include provisions for post-construction operations and maintenance, a stormwater operation and maintenance ordinance can augment existing local stormwater management ordinances. Like the model ordinance in **Appendix C**, a stormwater operation and maintenance ordinance should specify requirements for an operation and maintenance plan, the entity responsible for long-term maintenance, and the frequency of inspections (CWP, 2002c).

The Center for Watershed Protection (www.cwp.org) and the U.S. Environmental Protection Agency Office of Water (www.epa.gov/nps/ordinance/index.htm) provide information on local stormwater-related ordinances, including model ordinances and examples of local ordinances from communities across the United States.

The model ordinances in **Appendix C** of this Manual are provided for informational purposes only and should not be adopted as a legal requirement without modification to fit the specific needs of the municipality and the local water resource conditions.

5.6 Public Education and Outreach

Nearly all source control and pollution prevention techniques rely on some level and form of public education. In some cases, education efforts must be targeted at municipal officials and public works employees (e.g., stormwater ordinances, roadway deicing application, storm drainage system maintenance). The general public, including business owners and operators, plays an important role in almost all of the source control and pollution prevention measures described in this chapter. Often, the public is not aware of the critical role they have in protecting water resources. Public education is an important part of an overall pollution prevention and source control program because it raises awareness of both personal responsibilities and the responsibilities of others relative to environmental protection, and teaches people what individual actions they can take to prevent pollution. This increased understanding has the additional benefit of fostering support for other stormwater management efforts.

This section describes some common general techniques for public education that can be used in addition to the specific methods described in earlier sections.

Public Education Materials

Public education campaigns can consist of a variety of elements including:

- *Educational displays, pamphlets, booklets, and utility stuffers*
- *Use of the media (newspapers, television, radio)*
- *Promotional giveaways (hats, t-shirts, bumper stickers, etc.)*
- *Stormwater educational materials*
- *Classroom education*

The choice of outreach materials is dependent upon the resources available and the target audience. A variety of general educational materials on stormwater and pollution prevention are available from state and federal government agencies, as well as education and industry groups (see references below for a partial list of such contacts).

Businesses

Because many commercial activities can potentially contribute to stormwater pollution, businesses are a common target for public education. Public outreach activities should be targeted to the specific business audience, i.e., automotive-related, dry cleaners, etc. Materials can include posters, calendars, flyers, brochures, handbooks, and best management practice (BMP) fact sheets targeted to the specific industry. Because of the wide variety of businesses, public education and outreach programs should prioritize efforts on business types that might have the most potential to contribute to stormwater pollution or might be most receptive to outreach.

Municipal Officials

Because of their involvement in establishing and implementing local source control and pollution prevention measures, municipal officials are an important target audience for education related to stormwater management and pollution prevention. The Nonpoint Education for Municipal Officials (NEMO) Project (http://www.nemo.uconn.edu) is an educational program for Connecticut local land use officials that addresses the relationship between land use and natural resource protection. NEMO is a collaboration between three branches of the University of Connecticut: the Cooperative Extension System, the Natural Resources Management and Engineering Department, and the Connecticut Sea Grant College Program. NEMO's educational programs are available to communities free of charge. In addition, the program provides educational publications and in some cases, maps, web-based information, and individual consultation. The materials cover a range of topics from open space planning to site plan review for stormwater management.

In addition to the information and assistance available through NEMO, DEP and other government and non-profit agencies provide a variety of outreach programs and materials focused on educating local decision-makers about stormwater management and pollution prevention.

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Chapter 6
Introduction to Stormwater Treatment Practices

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6.1 Introduction

This chapter introduces stormwater treatment practices that are acceptable for water quality treatment in Connecticut, either alone or in combination with source controls and other treatment practices. The following sections describe three categories of stormwater treatment practices:

- *Primary Stormwater Treatment Practices*
- *Secondary Stormwater Treatment Practices*
- *Stormwater Treatment Train*

This chapter also provides general information on maintenance considerations and performance monitoring for stormwater treatment practices.

Stormwater treatment practices are structural controls primarily designed to remove pollutants from stormwater runoff, but they also can provide other benefits including groundwater recharge, peak runoff attenuation, and stream channel protection. As described in Chapter Three of this Manual, stormwater treatment practices are one element of a comprehensive stormwater management strategy, and should be selected and designed only after consideration of effective site planning/design and source controls that can reduce the volume of runoff and the size and cost of stormwater treatment.

6.2 Primary Stormwater Treatment Practices

The stormwater treatment practices listed in this section, referred to as primary stormwater treatment practices, are capable of providing high levels of water quality treatment as stand-alone devices. A growing body of research on stormwater treatment practices throughout the United States, as well as field experience in Connecticut and other northeastern states, has demonstrated that these practices are capable of:

- *Capturing and treating the design water quality volume (WQV) or design water quality flow (WQF) (see Chapter Seven)*
- *Removing at least 80 percent of the average annual total suspended solids (TSS) load*
- *Removing at least 80 percent of floatable debris, including oil and petroleum products, for all flow rates up to the design water quality flow, either alone or in combination with pretreatment*
- *Acceptable performance or operational longevity in the field*

(NYDEC, 2001; MDE, 2000). The above performance standards assume that these stormwater treatment practices are properly selected, sited, designed, constructed, and maintained in accordance with the guidelines contained in this Manual.

The State of Connecticut has adopted the 80 percent TSS removal goal based on EPA guidance and its widespread use as a target stormwater quality performance standard. TSS is considered a suitable target pollutant constituent for a removal standard because of its widespread impact on water quality and aquatic habitat degradation, because many other pollutants including heavy metals, bacteria, and organic chemicals adsorb to sediment particles, and because it has been the most frequently and consistently sampled stormwater constituent (MADEP, 1997).

Primary stormwater treatment practices can be grouped into five major categories:

Stormwater Ponds: Stormwater ponds maintain either a permanent pool of water or a combination of a permanent pool and extended detention. The permanent pool of water in these systems enhances pollutant removal through mechanisms such as sedimentation, biological uptake, microbial breakdown, gas exchange, volatilization, and decomposition. This category of stormwater ponds does not include traditional dry detention ponds or dry flood control basins, which do not provide significant water quality treatment functions (see the Secondary Treatment Practices described in this chapter). Treatment practices in this category include:

- ❍ *Wet pond*
- ❍ *Micropool extended detention pond*
- ❍ *Wet extended detention pond*
- ❍ *Multiple pond system*

Stormwater Wetlands: Stormwater wetlands are constructed wetland systems designed to treat polluted stormwater runoff by several mechanisms, including sedimentation, adsorption, biological uptake, photodegradation, and microbial breakdown. Stormwater wetlands typically include sediment forebays, shallow and deep pool areas, meandering flow paths, and vegetative measures to enhance pollutant removal. Stormwater wetlands are engineered specifically for pollutant removal and flood control purposes. They typically do not have the full range of ecological functions of natural wetlands or wetlands constructed for compensatory storage or wetland mitigation. Stormwater wetland practices in this category include:

- ❍ *Shallow wetland*
- ❍ *Extended detention wetland*
- ❍ *Pond/wetland system*

Infiltration Practices: Infiltration practices are designed to capture, temporarily store, and infiltrate stormwater into porous soils. Pollutant removal occurs through adsorption of pollutants onto soil particles, and subsequent biological and chemical conversion in the soil. Infiltration practices aid in recharging groundwater but must be carefully designed and maintained to prevent clogging and system failure. Infiltration practices in this category include:

- ❍ *Infiltration trench*
- ❍ *Infiltration basin*

Filtering Practices: Filtering practices treat stormwater runoff by capturing, temporarily storing, and filtering stormwater through sand, soil, organic material, or other porous media. As the water flows through the filter media, sediment particles and attached pollutants, as well as some soluble pollutants, are removed through physical straining and adsorption. Pretreatment is generally required to remove debris and floatables, and prolong the life of the filter. Filtering practices in this category include:

- ❍ *Surface sand filter*
- ❍ *Underground sand filter*
- ❍ *Perimeter sand filter*
- ❍ *Bioretention*

Water Quality Swales: Water quality swales reduce the velocity of and temporarily store stormwater runoff and promote infiltration. Pollutant removal mechanisms in water quality swales are similar to constructed wetlands and include sedimentation, adsorption, biological uptake, and microbial breakdown. These practices differ from conventional grass channels and ditches that are primarily designed for conveyance, as they provide higher levels of pollutant removal. Practices in this category include:

- ❍ *Dry swale*
- ❍ *Wet swale*

The above practices generally have the highest removal efficiencies for pollutants such as nutrients and metals, in addition to TSS. Pollutant removal summary data for stormwater treatment practices are included in Chapter Eight.

Other stormwater treatment practices not listed above, such as the secondary treatment practices described in the following section, may be classified as primary practices at the discretion of the local review authority and/or DEP. In order to be considered a primary stormwater treatment practice, a practice must demonstrate the ability to treat the design water quality volume or an equivalent design water quality flow, meet the 80 percent TSS and floatables criteria, and have proven operational longevity. It is conceivable that as treatment systems age, they may lose their effectiveness and may further be considered a pollutant source. The following sections describe criteria for acceptance of new technologies as primary treatment practices.

6.3 Secondary Stormwater Treatment Practices

A number of stormwater treatment practices may not be suitable as stand-alone treatment because they either are not capable of meeting the water quality treatment performance criteria described in the previous section or have not yet received the thorough evaluation needed to demonstrate the capabilities for meeting the performance criteria. These practices, termed secondary stormwater treatment practices, generally fall into either of the following categories:

- *Conventional Practices*
- *Innovative/Emerging Technologies*

Table 6-1 summarizes the rationale for the limited use of these practices for water quality control, as well as applications suitable for their use, such as pretreatment or use in a treatment train to achieve multiple stormwater management objectives and to satisfy the design criteria in Chapter Seven (see Section 6.4 below). Chapter Eleven contains limited design guidance for these secondary practices.

6.3.1 Conventional Practices

Conventional or "public-domain" (as opposed to proprietary) secondary treatment practices are practices that have traditionally been used to provide some water quality benefits, but that do not provide the same level of treatment or broad water quality functions as primary stormwater treatment practices. Consequently, their application is limited to use as pretreatment or supplemental treatment practices in conjunction with primary practices (i.e., a treatment train), or to achieve other objectives such as groundwater recharge, channel protection, and peak runoff attenuation. Conventional secondary treatment practices addressed in this Manual include:

- *Dry Detention Ponds*
- *Underground Detention Facilities*
- *Deep Sump Catch Basins*
- *Conventional Oil/Particle Separators*
- *Dry Wells*
- *Permeable Pavement*
- *Vegetated Filter Strips and Level Spreaders*
- *Grass Drainage Channels*

6.3.2 Innovative/Emerging Technologies

The other category of secondary treatment practices addressed in this Manual includes innovative and emerging technologies, which are typically proprietary systems. Stormwater treatment practices are continually evolving in response to advances in treatment technology, availability and affordability of new technology, and recognition of new treatment needs. These innovative and emerging technologies are those for which preliminary performance data indicate that they may provide a valuable stormwater treatment function. However, unlike the primary stormwater treatment practices described previously in this chapter, these technologies have not been evaluated in sufficient detail to demonstrate proven capabilities for meeting established performance standards, including pollutant removal and field longevity (see **Table 6-1**).

The following section provides examples of recently developed innovative and emerging technologies for stormwater treatment. Chapter Eleven also provides limited design guidance for these technologies. As secondary treatment practices, innovative and emerging technologies are suitable for pretreatment or for use in a treatment train approach. Emerging technologies generally are also good candidates for stormwater retrofits and where land is unavailable for larger systems. Their use as standalone treatment devices (i.e., primary treatment practices) should be evaluated using consistent and technically rigorous protocols. This section describes recommended criteria for evaluating new or emerging stormwater treatment technologies. New or emerging technologies that meet these criteria may be acceptable as primary treatment practices.

Examples of Innovative and Emerging Technologies

Most innovative or emerging technologies are proprietary devices developed by various manufacturers and vendors. System designs vary considerably, although most currently available technologies generally can be grouped into one of the following categories:

Catch Basin Inserts: As the name implies, catch basin inserts are placed directly inside of existing catch basins to remove pollutants from stormwater. Stormwater flows into the catch basin and is treated as it passes through the structure. The insert consists of a structure, such as a tray, basket, or bag that typically contains a pollutant removal medium (i.e., filter media) and a method for suspending the structure in the catch basin (Lee, 2001). Although filter media is commonly used, basket-type inserts constructed of wire mesh and fabric bag-type inserts are also used without filter media for removing gross particles (i.e., trash and debris). Although they have the potential to remove total suspended solids, organics, and metals, the removal capabilities depend on the pollutant loading characteristics of the stormwater and the choice of filter medium. Because these devices are limited by the size of the catch basin, there is a relatively short contact time between stormwater and the media for

Table 6-1 Summary of Secondary Stormwater Treatment Practices

Practice	Reasons for Limited Use	Suitable Applications
Conventional Practices		
Dry Detention Ponds	○ Not intended for water quality treatment. Designed to empty out between storms; lack the permanent pool or extended detention required for adequate stormwater treatment ○ Settled particulates can be resuspended between storms	○ Flood control and channel protection
Catch Basins	○ Limited pollutant removal ○ No volume control ○ Resuspension of settled particulates	○ Pretreatment or in combination with other stormwater treatment practices ○ Stormwater retrofits
Conventional Oil/ Particle Separators	○ Limited pollutant removal ○ No volume control ○ Resuspension of settled particulates	○ Pretreatment or in combination with other stormwater treatment practices ○ Highly impervious areas with substantial vehicle traffic
Underground Detention Facilities	○ Not intended for water quality treatment ○ Particulates can be resuspended between storms	○ Flood control and channel protection ○ Space-limited or ultra-urban sites
Permeable Pavement	○ Reduced performance in cold climates due to clogging by road sand and salt ○ Porous asphalt or concrete recommended for limited use in Connecticut	○ Modular concrete paving blocks, modular concrete or plastic lattice, or cast-in-place concrete grids are suitable for use in spillover parking, parking aisles, residential driveways, and roadside rights-of-way
Dry Wells	○ Not intended as stand-alone stormwater runoff quality or quantity control ○ Potential for clogging/failure ○ Applicable to small drainage areas ○ Potential groundwater quality impacts	○ Infiltration of clean rooftop runoff ○ Stormwater retrofits ○ Space-limited ultra-urban ○ Pretreatment or in combination with other stormwater treatment practices
Vegetated Filter Strips	○ Typically, cannot alone achieve the 80% TSS removal goal	○ Pretreatment or in combination with other treatment practices ○ Limited groundwater recharge ○ Outer zone of a stream buffer ○ Residential applications and parking lots
Grass Drainage Channels	○ Typically, cannot alone achieve the 80% TSS removal goal	○ Part of runoff conveyance system to provide pretreatment ○ Replace curb and gutter drainage ○ Limited groundwater recharge
Level Spreaders	○ Typically, cannot alone achieve the 80% TSS removal goal	○ Pretreatment or in combination with other treatment practices ○ Use with filter strips and at outlets of other treatment practices to distribute flow ○ Groundwater recharge
Innovative/Emerging Technologies		
Catch Basin Inserts	○ Limited performance data available ○ High maintenance and susceptible to clogging	○ Stormwater retrofits, ultra-urban sites ○ Small drainage areas without excessive solids loadings ○ Pretreatment or in combination with other treatment practices
Hydrodynamic Separators	○ Limited performance data available ○ Performance varies with flow rate	○ Pretreatment or in combination with other treatment practices ○ Stormwater retrofits, ultra-urban sites
Media Filters	○ Limited performance data available	○ Pretreatment or in combination with other treatment practices ○ Stormwater retrofits, ultra-urban sites
Underground Infiltration Systems	○ Limited performance data available	○ Groundwater recharge ○ Stormwater retrofits
Alum Injection	○ Requires ongoing operation and monitoring ○ Limited performance data available ○ Potential for negative impacts to downstream receiving waters	○ Stormwater retrofits, ultra-urban sites ○ Pretreatment or in combination with other treatment practices
Advanced Treatment	○ Requires ongoing operation and monitoring ○ High cost and level of complexity ○ Limited performance data available	○ Only as required, where other primary or secondary practices are insufficient

pollutant removal and little storage area for the material that is removed. Consequently, frequent maintenance is typically required to avoid clogging of the insert and there is the possibility of re-suspension of filtered pollutants (Washington, 2000).

Hydrodynamic Separators: This group of stormwater treatment technologies is designed to remove large particle total suspended solids and large oil droplets. They consist primarily of cylindrical-shaped devices that are designed to fit in or adjacent to existing stormwater drainage systems (Washington, 2000). The most common mechanism used in these devices is vortex-enhanced sedimentation, also called swirl concentration. In these structures, often called swirl concentrators, stormwater enters as tangential inlet flow into the side of the cylindrical structure. As the stormwater spirals through the chamber, the swirling motion causes the sediments to settle by gravity, removing them from the stormwater (EPA, 2002). Some devices also have compartments or chambers to trap oil and other floatables.

Although swirl concentration is the technology employed by most hydrodynamic separators, some systems use circular screening systems or engineered cylindrical sedimentation. Circular screened systems use a combination of screens, baffles, and inlet and outlet structures to remove debris, large particle total suspended solids, and large oil droplets. Structures using engineered cylindrical sedimentation use an arrangement of internal baffles and an oil and sediment storage compartment. Other proprietary technologies incorporate an internal high flow bypass with a baffle system in a rectangular structure to simulate plug flow operation. When properly engineered and tested, these systems can also be an improvement over conventional oil/particle separators and offer removal efficiencies similar to swirl chamber technologies. Absorbent materials can also be added to these structures to increase removal efficiency of oil and hydrocarbons (Washington, 2000).

Media Filters: In this type of treatment practice, media is placed within filter cartridges that are typically enclosed in concrete vaults. Stormwater is passed through the media, which traps particulates and/or soluble pollutants. Various materials can be used as filter media including pleated fabric, activated charcoal, perlite, amended sand and perlite mixes, and zeolite. Selection of filter media is a function of the pollutants targeted for removal. Pretreatment prior to the filter media is typically necessary for stormwater with high total suspended solids, hydrocarbon, and debris loadings that may cause clogging and premature filter failure (Washington, 2000).

Underground Infiltration Systems: Various types of underground infiltration structures, such as pre-manufactured pipes, vaults, and modular structures, have been developed as alternatives to infiltration trenches and basins for space-limited sites and stormwater retrofit applications. Similar to traditional infiltration trenches and basins, these systems are designed to capture, temporarily store, and infiltrate the design water quality volume over several days. Performance of underground infiltration structures varies by manufacturer and system design. These systems are currently considered secondary treatment practices due to limited field performance data, although pollutant removal efficiency is anticipated to be similar to that of infiltration trenches and basins.

Advanced Treatment: The pollutant removal techniques utilized in drinking water treatment processes are potential advanced treatment options for stormwater (Lee, 2001). Alum has been used extensively as a coagulant in pond and lake management applications. Alum injection has also been used more recently in stormwater applications for reducing concentrations of fine sediment and phosphorus in stormwater discharges to eutrophic water bodies. Water-soluble anionic polyacrylamide (PAM) has also been used as a coagulant in drinking water treatment and pond dredging operations to enhance settling of solids. PAM has also been land applied as an erosion and sedimentation control measure. Recently, the use of PAM in pre-formed shapes such as logs in ditches or open swales has been introduced to enhance removal of fine sediment in stormwater runoff. However, the practicability of methods such as ion exchange, reverse osmosis, disinfection, and ultrafiltration is undocumented for stormwater treatment. The success of these methods in drinking water treatment suggests that they may have potential applications in areas where conventional stormwater treatment methods are unable to meet stringent stormwater quality standards or established waste load allocations. However, these technologies are beyond the scope of this Manual.

Criteria for Evaluating New Practices

New and emerging stormwater treatment practices may be acceptable as primary treatment practices if they demonstrate the ability to achieve treatment results consistent with the primary treatment practices described at the beginning of this chapter, specifically:

- *Capture and treatment of the design water quality volume (WQV) or design water quality flow (WQF)*

- *Removal of at least 80 percent of the average annual total suspended solids (TSS) load*
- *Removing at least 80 percent of floatable debris, including oil and petroleum products, for all flow rates up to the design water quality flow (WQF), either alone or in combination with pretreatment*
- *Acceptable performance or operational longevity in the field*
- *Automatic operation during runoff events (i.e., no need for manual activation)*

These capabilities must be demonstrated through field and laboratory testing. Independent validation of data that support specific treatment technology performance claims is recommended. Field performance data should come from field studies conducted under a variety of conditions (e.g., flow rates, contaminant loadings, antecedent moisture conditions, rainfall distribution, land use, percent imperviousness, maintenance intervals) (TARP, 2001). Ideally, the field studies should be conducted over a one-year demonstration period, including cold weather and winter conditions, to capture possible seasonal variations in performance and performance variations as a function of rainfall intensity.

Field data is valuable for verifying performance under actual field conditions. However, the variability of site conditions leads to site-specific performance validation that may be difficult to develop into sizing methodologies. It is recommended that laboratory testing be conducted to establish performance curves for technologies over the full operating range of the system. Performance curves based on laboratory data for various technologies, developed using the same test criteria, applied to the same rainfall and TSS removal model, enable direct comparison between technologies. Laboratory testing must be conducted in accordance with an established protocol for known particle sizes in known concentrations. The Maine Department of Environmental Protection has established one such protocol for comparing innovative technologies.

Performance claim data sets should be collected under a Quality Assurance Project Plan (QAPP) to ensure that the data sets meet data quality objectives and are defensible, and should include flow rates, residence times, and rainfall intensity data with which to interpret these claims. USEPA provides guidance on the development and minimum requirements for a QAPP. (See USEPA references at the end of this chapter.) Standardized test methods and procedures must be used in the collection of data. For example, ASTM methods for flow measurement methods, ASCE hydraulic flow estimation methods, and EPA test methods for water quality analysis are typical standardized test methods. (See TARP (2001)) for a listing of standardized methods for flow and water constituent analysis).

It is recommended that stormwater quality data be collected in accordance with guidance outlined in the Technology Acceptance and Reciprocity Partnership (TARP) Stormwater BMP Demonstration Protocol (2001). The TARP Stormwater BMP Demonstration Protocol has been endorsed by the states of Massachusetts, New York, New Jersey, Illinois, California, Maryland, Pennsylvania, Texas and Virginia to provide a uniform method for demonstrating stormwater technologies and developing test quality assurance plans for certification or verification of performance claims. Treatment efficiencies should be calculated using methods outlined in the joint EPA and ASCE technical memorandum *Determining Urban Stormwater Best Management Practice (BMP) Removal Efficiencies* (URS Greiner Woodward Clyde et al., 1999). In addition, to demonstrate that the performance claims are reliable, significant, and within confidence limits, statistical evaluation of the data must be performed and made available. Performance claims should be given with appropriate confidence intervals (i.e., removal rate of 85% ± 5% at a 95% confidence interval). The EPA Data Quality Assessment Guidance Manual (EPA, 1998) provides information on statistical methods for comparison and validation of data sets.

In addition to performance claims and validation, the following specifications for the treatment technology should be provided:

- *Description of the underlying scientific and engineering principles*
- *Standard drawings, including a process flow diagram*
- *Minimum siting and design specifications necessary to achieve the stated performance*
- *The full range of operating conditions for the technology, including minimum, maximum, and optimal conditions to meet the stated performance claims (flow rate, residence time, rainfall intensity, etc.)*
- *Minimum maintenance requirements to sustain the stated performance*
- *Description of hydraulics and system sizing to meet the performance claims*
- *Discussion of any pretreatment required to meet the stated performance claims*

- *Identification of any special licensing or hauling requirements, safety issues or access requirements associated with installation and/or operation and maintenance*
- *Discussion of the generation, handling, removal and disposal of any discharges, emissions, or other waste byproducts of the treatment technology*

(TARP, 2001). Evaluation protocols and methods similar to those of the TARP Stormwater BMP Demonstration Protocol have also been developed through EPA's Environmental Technology Verification (ETV) program. With funding from the ETV program, the Civil Engineering Research Foundation established the Environmental Technology Evaluation Center (EvTEC), an independent, non-profit verification center that evaluates environmental technologies. EvTEC is collaborating with the Washington State Department of Transportation to verify performance of innovative stormwater treatment practices under field operating conditions. These evaluations are expected to provide comparable, peer-reviewed performance data on these systems (CERF, 2002).

EPA and NSF International, an independent, non-profit testing organization, have developed a testing protocol under the ETV program to determine the viability of runoff treatment technologies and other wet weather flow controls, including urban runoff, combined sewer overflows (CSO), and sanitary sewer overflows (SSO). Participants in the study include vendors who want to demonstrate the effectiveness of their technologies. Results of the pilot will be useful to a variety of stakeholders including municipalities, businesses, vendors, consulting engineers, and regulatory agencies. Once verification reports have been completed, vendors may use the results in their marketing efforts. Results will be made publicly available through EPA's and NSF's Web sites at http://www.epa.gov/etv and http://www.nsf.org/etv, respectively.

6.4 Stormwater Treatment Train

Stormwater treatment practices can be combined in series to enhance pollutant removal or achieve multiple stormwater objectives. The use of a series of treatment practices, as well as site planning techniques and source controls, is referred to as "stormwater treatment trains". The use of a treatment train approach can:

- *Increase the level and reliability of pollutant removal*
- *Accomplish multiple stormwater management objectives (pollutant removal, groundwater recharge, channel protection, peak runoff attenuation, etc.)*
- *Increase the lifespan of treatment devices by distributing pollutant removal over multiple practices or controls*
- *Reduce the potential for resuspension of sediment by reducing flow velocities and increasing flow paths*
- *Allow the use of a wider array of treatment practices, including supplemental practices for pretreatment*

A treatment train may consist of the following types of practices in series to satisfy the design criteria in Chapter Seven:

- *Multiple primary treatment practices*
- *A combination of primary and secondary treatment practices*
- *Multiple secondary treatment practices (at the discretion of the review authority)*

The use of multiple stormwater treatment practices increases the maintenance required to preserve the overall effectiveness of the system. In general, the least expensive and most easily maintained components should be placed at the most upstream point in the treatment train to reduce the maintenance requirements of the downstream components (Metropolitan Council, 2001). The individual treatment practice descriptions in Chapter Eleven include guidance on routine and non-routine maintenance.

6.5 Maintenance

Stormwater treatment practices require regular maintenance to perform successfully. Failure to perform adequate maintenance can lead to reductions in pollutant removal efficiency or actually increase pollutant loadings and aggravate downstream impacts. Stormwater treatment practices should be routinely inspected and maintained following construction to ensure that the controls are in proper working condition and operating as designed. General maintenance guidelines for stormwater treatment practices are summarized below. Chapter Eleven contains recommended maintenance for specific stormwater treatment practices. **Appendix E** contains maintenance inspection checklists for specific stormwater treatment practices. Additional information on maintenance of stormwater treatment practices can be found in the documents listed at the end of this chapter.

General maintenance requirements for stormwater treatment practices include:

Inspections: Inspections should be performed at regular intervals to ensure proper operation of stormwater treatment practices. Inspections should be conducted at least annually, with additional inspections following large storms. Inspections should include a comprehensive visual check for evidence of the following (not all items apply to every treatment practice):

- *Accumulation of sediment or debris at inlet and outlet structures*
- *Erosion, settlement, or slope failure*
- *Clogging or buildup of fines on infiltration surfaces*
- *Vegetative stress and appropriate water levels for emergent vegetation*
- *Algae growth, stagnant pools, or noxious odors*
- *Deterioration of pipes or conduits*
- *Seepage at the toe of ponds or wetlands*
- *Deterioration or sedimentation in downstream channels and energy dissipators*
- *Evidence of vandalism*
- *Evidence of structural damage by beavers, muskrats, and other wildlife*

Routine Maintenance: Routine maintenance should be performed on a regular basis to maintain proper operation and aesthetics. Routine maintenance should include:

- *Debris and litter removal*
- *Silt and sediment removal*
- *Terrestrial vegetation maintenance*
- *Aquatic vegetation maintenance*
- *Maintenance of mechanical components (valves, gates, access hatches, locks)*

Non-routine Maintenance: Non-routine maintenance refers to corrective measures taken to repair or rehabilitate stormwater controls to proper working condition. Non-routine maintenance is performed as needed, typically in response to problems detected during routine maintenance and inspections, and can include:

- *Erosion and structural repair*
- *Sediment removal and disposal*
- *Nuisance control (odors, mosquitoes, weeds, excessive litter)*

Stormwater treatment practice operation and maintenance requirements are an integral part of a site stormwater management plan (see Chapter Nine). These requirements should include, at a minimum, detailed inspection and maintenance tasks, schedules, responsible parties, and financing provisions. The owner typically maintains stormwater treatment practices at commercial, industrial, and rental residential developments. These facilities generally have staff dedicated to maintenance activities or contract for such services. Maintenance of non-rental residential installations is typically performed by private landowners or property/homeowners associations, which in many cases do not have the technical expertise, resources, or funds to inspect and maintain their stormwater systems. In some cases, local government may accept responsibility for inspecting and maintaining stormwater treatment practices. Local governments should require legally binding maintenance agreements for stormwater treatment practices to clearly delineate maintenance responsibilities. Potential funding mechanisms include general tax revenues, stormwater utility fees, inspection or permit fees, and dedicated funds from land developers. Public education is critical for the success of any stormwater financing program.

Many municipalities consider stormwater treatment practices such as ponds, wetlands, and other "wet" treatment systems as regulated wetland areas, and therefore subject to local inland wetlands and watercourses regulations. Sediment removal and other common maintenance activities may require approval from the local Inland Wetlands and Watercourses Commission, which presents a potential regulatory hurdle to consistent maintenance. To facilitate this approval process, municipalities could issue up to a five-year maintenance permit in conjunction with the primary Inland Wetlands and Watercourses permit for the development or redevelopment project. The permit holder would be responsible for renewing or requesting reissuance of the maintenance permit at five-year intervals. Municipalities should identify all such stormwater management facilities for which they are responsible and issue a five-year renewable maintenance permit. This type of an approach is analogous to DEP's renewable five-year maintenance permits issued to DOT and other state-regulated entities for statewide drainage maintenance activities.

6.6 Performance Monitoring

Currently, there are very limited performance data for stormwater treatment practices in the State of Connecticut. Performance data from the majority of previous monitoring studies conducted throughout the United States are limited by differences in design, performance goals, site parameters, storm events, flow and pollutant loadings, seasonal variations, monitoring methods, efficiency calculation methods or simply by the lack of or inadequacy of information. Several major initiatives are underway nationally to provide a more useful set of data on the effectiveness of individual stormwater treatment practices, and to better understand the relationship between treatment practice design and performance. These include:

- *The Center for Watershed Protection's* National Pollutant Removal Performance Database *(Winer, 2000)*
- *The American Society of Civil Engineers (ASCE)* National Stormwater Best Management Practices (BMP) Database *(Urban Water Resources Research Council of ASCE and Wright Water Engineers, Inc., 2001)*
- *Water Environment Research Foundation (WERF)* Critical Assessment of Stormwater Control (BMP) Selection Issues *(WERF, in progress)*

These databases contain the results of performance studies for individual stormwater treatment practices throughout the United States. While they provide a starting point for pollutant removal estimates, the usefulness of the data is still extremely limited for many of the reasons stated above. The reliability of the data will continue to increase as the results from additional studies are added.

Very few performance monitoring studies have been performed in Connecticut or elsewhere in New England. Performance monitoring is recommended for new and existing stormwater treatment practices in Connecticut to develop a representative and reliable performance database that is specific to the State of Connecticut. Performance monitoring is designed to provide information on the following issues:

- *What degree of pollution control does the treatment practice provide under typical operating conditions?*
- *How does efficiency vary from pollutant to pollutant?*
- *How does efficiency vary with various input concentrations?*
- *How does efficiency vary with storm characteristics such as rainfall amount, rainfall density, antecedent weather conditions?*
- *How do design variables affect performance?*
- *How does efficiency vary with different operational and/or maintenance approaches?*
- *Does efficiency improve, decay, or remain the stable over time?*
- *How does the system's efficiency, performance, and effectiveness compare relative to other stormwater treatment practices?*
- *Does the treatment practice reduce toxicity to acceptable levels?*
- *Does the treatment practice cause an improvement or protect in downstream biotic communities?*
- *Does the treatment practice have potential downstream negative impacts?*

(URS Greiner Woodward Clyde et al., 1999). Standardized test methods and procedures should be used for stormwater performance monitoring studies. Performance monitoring should be consistent with the methods and protocols described previously in this chapter for evaluating new stormwater treatment technologies and the guidance documents referenced therein.

Additional Information Sources

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Chapter 7
Hydrologic Sizing Criteria for Stormwater Treatment Practices

Volume II: Design

Chapter 7

Hydrologic Sizing Criteria for Stormwater Treatment Practices

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7.1 Introduction

This chapter presents a recommended approach for sizing stormwater treatment practices in the State of Connecticut. Although the primary focus of this Manual is on stormwater quality, the management of stormwater quantity is an important related concern. Therefore, the sizing criteria in this chapter are designed to achieve both water quality and quantity control objectives. The recommended sizing criteria have been adapted from the Center for Watershed Protection's Unified Sizing Criteria, which is one of the more comprehensive approaches for sizing stormwater treatment practices developed to date. This approach has been implemented in several other states including Maryland, New York, Vermont, and Georgia.

The sizing approach described in this chapter is intended to manage the full spectrum of storm flows and their associated water quality and quantity impacts. These range from small, frequent storms that are responsible for a majority of the annual runoff volume and pollutant loads to large, infrequent events which are responsible for nuisance and catastrophic flooding. Stormwater treatment practices should be designed to accomplish the following primary objectives:

- *Pollutant reduction*
- *Runoff volume reduction and groundwater recharge*
- *Stream channel protection and peak flow control*

The following sections of this chapter describe criteria and methods for sizing stormwater treatment practices to meet these objectives. These criteria are intended to be consistent with local subdivision and planning/ zoning ordinances of most municipalities throughout the state, particularly regarding peak flow control requirements. Some differences may exist between the criteria presented in this chapter and local requirements. Local requirements should be consulted in addition to these criteria. However, the criteria presented in this chapter are recommended where local regulations are less stringent.

7.2 Criteria Applicability

The design criteria presented in this chapter are generally applicable to the following types of new development and redevelopment projects, including phased developments:

- *Any development resulting in the disturbance of greater than or equal to one acre of land*
- *Residential development consisting of 5 or more dwelling units*
- *Residential development consisting of fewer than 5 dwelling units involving construction of a new road or reconstruction of an existing road*
- *Residential development consisting of fewer than 5 dwelling units where imperviousness of the site after construction exceeds 30 percent*
- *Stormwater discharge to wetlands/watercourses*
- *New stormwater discharges located less than 500 feet from tidal wetlands*
- *Land uses or activities with potential for higher pollutant loadings (see* ***Table 7-5****), excluding the groundwater recharge criterion*
- *Industrial and commercial development projects which result in 10,000 sq. ft. or greater of impervious surface*
- *New highway, road, and street construction*
- *Modifications to existing storm drainage systems*

These and other types of projects not listed above, such as single family residential development, are encouraged to incorporate alternative site design, low impact development practices, and source controls to reduce imperviousness, runoff volumes, and stormwater pollutant sources.

Table 7-1 Summary of Stormwater Treatment Practice Sizing Criteria

Sizing Criteria	Description	Post-Development Storm Magnitude
Pollutant Reduction	***Water Quality Volume (WQV)*** Volume of runoff generated by one inch of rainfall on the site WQV = (1")(R)(A)/12 WQV = water quality volume (ac-ft) R = volumetric runoff coefficient = 0.05+0.009(I) I = percent impervious cover A = site area in acres	First one inch of rainfall
	Water Quality Flow (WQF) Peak flow associated with the water quality volume calculated using the NRCS Graphical Peak Discharge Method	
Groundwater Recharge and Runoff Volume Reduction	***Groundwater Recharge Volume (GRV)*** Maintain pre-development annual groundwater recharge volume to the maximum extent practicable through the use of infiltration measures	Not applicable
	Runoff Capture Volume (RCV) Retain on-site the volume of runoff generated by one inch of rainfall for new stormwater discharges located within 500 feet of tidal wetlands RCV = (1")(R)(A)/12 RCV = runoff capture volume (ac-ft) R = volumetric runoff coefficient = 0.05+0.009(I) A = site area in acres	First one inch of rainfall
Peak Flow Control	***Stream Channel Protection*** Control the 2-yr, 24-hour post-development peak flow rate to 50 percent of the 2-yr, 24-hr pre-development level or to the 1-yr, 24-hr pre-development level ("Two-Year Over-Control").	2-year, 24-hour rainfall
	Conveyance Protection Design the conveyance system leading to, from, and through stormwater management facilities based on the 10-year, 24-hour storm.	10-year, 24-hour rainfall
	Peak Runoff Attenuation Control the post-development peak discharge rates from the 10-, 25-, and 100-year storms to the corresponding pre-development peak discharge rates, as required by the local review authority.	10-, 25-, and 100-year 24-hour rainfall
	Emergency Outlet Sizing Size the emergency outlet to safely pass the post-development peak runoff from, at a minimum, the 100-year storm in a controlled manner without eroding the outlet works and downstream drainages.	100-year, 24-hour rainfall

Consult local regulations for additional criteria. The above criteria are recommended where local regulations are less stringent.

Some of the sizing criteria presented in this chapter may not be practical to meet due to space limitations, soil conditions, and other site constraints which are common in redevelopment or retrofit applications. Treatment practices sized for smaller treatment volumes/flows or exemptions from certain criteria may be appropriate in these situations, at the discretion of the review authority. Conditions where the recommended sizing criteria may not be applicable are identified in the following sections.

7.3 Criteria Summary

Table 7-1 summarizes the hydrologic sizing criteria for stormwater treatment practices in Connecticut. As indicated in **Table 7-1**, the sizing criteria are based on stormwater runoff generated by 24-hour duration storms of various return frequencies (i.e., design storms). **Table 7-2** lists 24-hour design rainfall depths for each county in Connecticut. The rationale for and application of these criteria are described in the following sections.

Table 7-2
Design Rainfall Amounts By County

	24-Hour Rainfall Amount (inches)				
County	1-yr	2-yr	10-yr	25-yr	100-yr
Fairfield	2.7	3.3	5.0	5.7	7.2
Hartford	2.6	3.2	4.7	5.5	6.9
Litchfield	2.6	3.2	4.7	5.5	7.0
Middlesex	2.7	3.3	5.0	5.6	7.1
New Haven	2.7	3.3	5.0	5.6	7.1
New London	2.7	3.4	5.0	5.7	7.1
Tolland	2.6	3.2	4.8	5.5	6.9
Windham	2.6	3.2	4.8	5.5	6.9

Source: TP-40, Department of Commerce, Weather Bureau, May 1961; NWS Hydro-35, Department of Commerce, National Weather Service, June 1977.

7.4 Pollutant Reduction

The pollutant reduction criterion is designed to improve the water quality of stormwater discharges by treating a prescribed water quality volume or associated peak flow, referred to as the water quality flow. Most treatment practices described in this Manual use a volume-based sizing criterion. The exceptions are grass drainage channels, proprietary stormwater treatment devices, and flow diversion structures, where a peak flow rate is utilized.

7.4.1 Water Quality Volume (WQV)

Description

The water quality volume (WQV) is the amount of stormwater runoff from any given storm that should be captured and treated in order to remove a majority of stormwater pollutants on an average annual basis. The recommended WQV, which results in the capture and treatment of the entire runoff volume for 90 percent of the average annual storm events, is equivalent to the runoff associated with the first one-inch of rainfall. The WQV is calculated using the following equation:

$$WQV = \frac{(1'')(R)(A)}{12}$$

where: WQV = water quality volume (ac-ft)
R = volumetric runoff coefficient
= 0.05+0.009(I)
I = percent impervious cover
A = site area in acres

- *The volumetric runoff coefficient R can also be determined from commonly available tabulated values for various land use, vegetative cover, soil, and ground slope conditions. However, the use of the above equation is recommended since it is directly related to the amount of impervious cover at a site, thereby providing incentive to reduce site imperviousness and the required runoff treatment volume. Reducing impervious cover using the site planning and design techniques described in Chapter Four can significantly reduce the WQV.*
- *Impervious cover should be measured from the site plan and includes all impermeable surfaces that are directly connected to the stormwater treatment practice such as paved and gravel roads, rooftops, driveways, parking lots, sidewalks, pools, patios and decks. In the absence of site-specific information or for large residential developments, impervious cover may be estimated based on average impervious coverage values for various parcel sizes listed in* ***Table 7-3****. The values shown in* ***Table 7-3*** *were derived from research by the University of Connecticut, Cooperative Extension System NEMO Project (Prisloe et al.,).*
- *The WQV should be treated by an acceptable stormwater treatment practice or group of practices described in this Manual. The WQV should be used for the design of the stormwater treatment practices described in this Manual, except grass drainage channels and proprietary stormwater treatment devices (e.g., hydrodynamic separators, catch basin inserts, and media filters), which should be designed based on the water quality flow (WQF).*

Table 7-3 Residential Land Use Impervious Cover	
Parcel Size (acres)	**Average Percent Impervious Cover**
<1/8	39
1/8 to 1/4	28
1/4 to 1/2	21
1/2 to 3/4	16
3/4 to 1	14
1 to 11/2	10
11/2 to 2	9
>2	8

Rationale

The above approach is similar to water quality sizing criteria that have been adopted elsewhere in the United States for the design of stormwater treatment practices. These criteria are intended to remove the majority of pollutants in stormwater runoff at a reasonable cost by capturing and treating runoff from small, frequent storm events that account for a majority of the annual pollutant load, while bypassing larger, infrequent storm events that account for a small percentage of the annual pollutant load. This approach is based on the "first flush" concept, which assumes that the majority of pollutants in urban stormwater runoff are contained in the first half-inch to one-inch of runoff primarily due to pollutant wash-off during the first portion of a storm event. Early studies in Florida determined that the first flush generally carries 90 percent of the pollution from a storm (Novotny, 1995). As a result, treatment of the first half-inch of runoff was adopted as a water quality volume sizing criterion requirement throughout much of the United States. More recent research has shown that pollutant removal achieved using the half-inch rule drops off considerably as site imperviousness increases.

A number of alternative water quality sizing methods were developed to achieve higher pollutant removals for a wider range of site imperviousness. One of the more common methods is known as the "90 Percent Rule", in which the water quality volume is equal to the storage required to capture and treat 90 percent of the annual runoff events (approximately 90 percent of the annual runoff pollutant load) based on analysis of historical precipitation records. The specific rainfall event captured is the storm event that is less than or equal to 90 percent of all 24-hour storms on an average annual basis. In the northeastern U.S., the 90 percent rainfall event is equal to approximately one inch, which is consistent with the recommended WQV sizing criteria for Connecticut.

7.4.2 Water Quality Flow (WQF)

Description

The water quality flow (WQF) is the peak flow rate associated with the water quality design storm or WQV. Although most of the stormwater treatment practices in this Manual should be sized based on WQV, some treatment practices such as grass drainage channels and proprietary treatment devices (designed to treat higher flow rates, thereby requiring less water quality storage volume) are more appropriately designed based on peak flow rate. In this approach, a stormwater treatment facility must have a flow rate capacity equal to or greater than the WQF in order to treat the entire water quality volume (Adams, 1998). In addition, flow diversion structures for off-line stormwater treatment practices can also be designed to bypass flows greater than the WQF.

The WQF should be calculated using the WQV described above and the NRCS, TR-55 Graphical Peak Discharge Method. The procedure is based on the approach described in Claytor and Schueler, 1996 and is summarized in **Appendix B**. Design guidance for flow diversion structures is also found in **Appendix B**.

Rationale

The use of the NRCS, TR-55 Graphical Peak Discharge Method in conjunction with the water quality volume for computing the peak flow associated with the water quality design storm is preferable to both traditional SCS Methods and the Rational Equation, both of which have been widely used for peak runoff calculations and drainage design. The traditional SCS TR-55 methods are valuable for estimating peak discharge rates for large storms (i.e., greater than 2 inches), but can significantly underestimate runoff from small storm events (Claytor and Schueler, 1996). Similarly, the Rational Equation may be appropriate for estimating peak flows for small urbanized drainage areas with short times of concentration, but does not estimate runoff volume and is based on many restrictive assumptions regarding the intensity, duration, and aerial coverage of precipitation. The Rational Equation is highly sensitive to the time of concentration and rainfall intensity, and therefore should only be used with reliable intensity, duration, frequency (IDF) tables or curves for the storm and region of interest (Claytor and Schueler, 1996).

7.5 Groundwater Recharge and Runoff Volume Reduction

This criterion is designed to reduce stormwater runoff volumes and maintain groundwater recharge rates to pre-development levels. The criterion includes two components: groundwater recharge and runoff capture, which are described below.

7.5.1 Groundwater Recharge Volume (GRV)

Description

The groundwater recharge criterion is intended to maintain pre-development annual groundwater recharge volumes by capturing and infiltrating stormwater runoff. The objective of the groundwater recharge criterion is to maintain water table levels, stream baseflow, and wetland moisture levels. Maintaining pre-development groundwater recharge conditions can also reduce the volume requirements dictated by the other sizing criteria (i.e., water quality, channel protection, and peak flow control) and the overall size and cost of stormwater treatment practices.

The groundwater recharge volume (GRV) is the post-development design recharge volume (i.e., on a storm event basis) required to minimize the loss of annual pre-development groundwater recharge. The GRV is determined as a function of annual pre-development recharge for site-specific soils or surficial materials, average annual rainfall volume, and amount of impervious cover on a site. Several approaches can be used to calculate the GRV:

- ***Hydrologic Soil Group Approach:*** *This method was first developed and adopted by the state of Massachusetts, and has since been implemented in several other states including Maryland and Vermont. This approach involves determining the average annual pre-development recharge volume at a site based on the existing site hydrologic soil groups (HSG) as defined by the United States Natural Resources Conservation Service (NRCS) County Soil Surveys (MADEP, 1997). Based on this approach, the GRV can be calculated as the depth of runoff to be recharged, multiplied by the area of impervious cover, as shown below:*

$$GRV = \frac{(D)(A)(I)}{12}$$

where:
- GRV = groundwater recharge volume (ac-ft)
- D = depth of runoff to be recharged (inches), see **Table 7-4**
- A = site area (acres)
- I = post-development site imperviousness (decimal, not percent) for new development projects or the net increase in site imperviousness for re-development projects

Table 7-4
Groundwater Recharge Depth

NRCS Hydrologic Soil Group	Average Annual Recharge	Groundwater Recharge Depth (D)
A	18 inches/year	0.4 inches
B	12 inches/year	0.25 inches
C	6 inches/year	0.10 inches
D	3 inches/year	0 inches (waived)

Source: MADEP, 1997.
NRCS – Natural Resources Conservation Service

Where more than one hydrologic soil group is present on a site, a composite or weighted recharge value should be calculated based upon the relative area of each soil group. The GRV should be infiltrated in the most permeable soil group available on the site.

- ***USGS Surficial Materials Approach:*** *This approach is similar to the above hydrologic soil group method, except the pre-development average annual recharge quantities and recharge depths are based on the predominant surficial materials classifications on the site (coarse-grained stratified drift versus glacial till and bedrock) as determined from U.S. Geological Survey (USGS) mapping. In areas underlain by coarse-grained stratified drift, average annual recharge is approximately three times greater than from till and bedrock areas. Areas of coarse-grained stratified drift and till/bedrock can be obtained from USGS 7.5-minute topographic maps of 1:24,000 scale, available from the USGS and DEP. Estimates of average annual recharge values for these materials are available from the Connecticut Water Resources Inventory Bulletins prepared jointly by the USGS and DEP for the major drainage basins throughout the state.*

- ***Other Methods:*** *Pre-development recharge values and the required GRV can also be determined using the results of on-site soil evaluations or other geologic information provided that information sources and methods are clearly documented.*

Meeting the recharge requirement can be accomplished through the use of primary treatment practices (infiltration, bioretention, filtration, and swales), secondary treatment practices (drywells, permeable pavement, level spreaders), and non-structural site design techniques such as disconnection of rooftop runoff and grading. Stormwater ponds, wetlands, and sediment forebays generally are not suitable for groundwater recharge since they are either designed with impermeable bottoms or have significantly reduced permeability due to accumulation of fine sediment. When designing infiltration practices, a factor of safety should be used to account for potential compaction of soils by construction equipment, which can significantly reduce soil infiltration capacity and groundwater recharge. See the design sections of this Manual for guidance on the design and construction of infiltration practices to reduce this potential.

The GRV is considered as part of the total water quality volume (WQV) and therefore can be subtracted from the WQV, provided that the proposed infiltration measures are capable of infiltrating the required recharge volume. Reducing the WQV (and consequently the size and cost of stormwater treatment) is an additional incentive for meeting the groundwater recharge criterion. Additionally, both WQV and GRV are a function of site imperviousness, providing further incentive to minimize site impervious cover.

There are several instances where the groundwater recharge criterion should be waived to protect against contamination of drinking water supplies and mobilization of existing subsurface contamination. Infiltration of stormwater is not recommended under the following site conditions:

- ***Land Uses or Activities with Potential for Higher Pollutant Loads:*** *Infiltration of stormwater from these land uses or activities (**Table 7-5**), also referred to as stormwater "hotspots," can contaminate public and private groundwater supplies. Infiltration of stormwater from these land uses or activities may be allowed by the review authority with appropriate pretreatment. Pretreatment could consist of one or a combination of the primary or secondary treatment practices described in this Manual provided that the treatment practice is designed to remove the stormwater contaminants of concern.*

- ***Subsurface Contamination:*** *Infiltration of stormwater in areas with soil or groundwater contamination such as brownfield sites and urban redevelopment areas can mobilize contaminants.*

- ***Groundwater Supply Areas:*** *Infiltration of stormwater can potentially contaminate groundwater drinking water supplies in public drinking water aquifer recharge areas and wellhead protection areas.*

Rationale

The objective of the groundwater recharge criterion is to mimic the average annual recharge rate for pre-development site conditions. The recommended approach for calculating the GRV (i.e., the required stormwater infiltration volume) is a function of post-development site imperviousness and the prevailing surface permeability and infiltration capacity. The hydrologic soil group approach uses the widely available NRCS Soil Survey maps and estimates of average annual infiltration rates for each hydrologic soil group. This method has been adopted in Massachusetts and other northeastern states, which have humid climates and receive approximately 44 inches of average annual rainfall. The recharge factors developed for this approach are also valid for Connecticut, which has similar rainfall, soils, and climate.

The alternative surficial materials approach may be less accurate than other soil-specific methods for estimating site-specific infiltration rates. The annual recharge values for surficial material categories are based on basin-wide analyses of stratified drift and till, which may not be applicable to specific sites. However, the approach is believed to be suitable for estimating the required recharge volume and utilizes readily available, published information from the USGS and DEP.

7.5.2 Runoff Capture Volume (RCV)

Description

The objective of the runoff capture criterion is to capture stormwater runoff to prevent the discharge of pollutants, including "unpolluted" fresh water, to sensitive coastal receiving waters and wetlands. The runoff capture criterion applies to new stormwater discharges located less than 500 feet from tidal wetlands, which are not fresh-tidal wetlands. The stormwater runoff volume generated by the first inch of rainfall must be retained on-site for such discharges. The runoff capture volume is equivalent to the WQV and can be calculated using the following equation:

Table 7-5 Land Uses or Activities with Potential for Higher Pollutant Loads

Land Use/Activities	
❍ Industrial facilities subject to the DEP Industrial Stormwater General Permit or the U.S. EPA National Pollution Discharge Elimination System (NPDES) Stormwater Permit Program[1]	❍ Road salt storage facilities (if exposed to rainfall)
❍ Vehicle salvage yards and recycling facilities	❍ Commercial nurseries
❍ Vehicle fueling facilities (gas stations and other facilities with on-site vehicle fueling)	❍ Flat metal rooftops of industrial facilities
❍ Vehicle service, maintenance, and equipment cleaning facilities	❍ Facilities with outdoor storage and loading/unloading of hazardous substances or materials, regardless of the primary land use of the facility or development
❍ Fleet storage areas (cars, buses, trucks, public works)	❍ Facilities subject to chemical inventory reporting under Section 312 of the Superfund Amendments and Reauthorization Act of 1986 (SARA), if materials or containers are exposed to rainfall
❍ Commercial parking lots with high intensity use (shopping malls, fast food restaurants, convenience stores, supermarkets, etc.)	❍ Marinas (service and maintenance)
❍ Public works storage areas	❍ Other land uses and activities as designated by the review authority

[1]Stormwater pollution prevention plans are required for these facilities. Pollution prevention and source controls are recommended for the other land uses and activities listed above.

$$RCV = \frac{(1'')(R)(A)}{(12)}$$

where: RCV = runoff capture volume (acre-feet)
R = volumetric runoff coefficient
I = percent impervious cover
A = site area in acres

Wet ponds designed with adequate storage volume to capture and retain the RCV or infiltration practices described in this Manual can be used to satisfy the runoff capture volume criterion.

Rationale

The runoff capture volume criterion is consistent with DEP coastal management policy and stormwater general permit requirements. Discharge of the "first-flush" of stormwater runoff into brackish and tidal wetlands is prohibited due to the resultant dilution of the high marsh salinity and encouragement of the invasion of brackish or upland wetland species such as Phragmites.

7.6 Peak Flow Control

Peak flow control criteria are intended to address increases in the frequency and magnitude of a range of potential flood conditions resulting from development. These include relatively frequent events that cause channel erosion, larger events that result in bankfull and overbank flooding, and extreme floods. The following sections describe sizing criteria for controlling peak flows, as well as for designing stormwater conveyance and emergency outlet structures. Natural Resource Conservation Service (NRCS) peak flow calculation methods such as TR-55 or TR-20 should be used to compute the required peak flow rates for each of the criteria described below.

7.6.1 Stream Channel Protection

Description

The stream channel protection criterion is intended to protect stream channels from erosion and associated sedimentation in downstream receiving waters and wetlands as a result of urbanization within a watershed. By restricting peak flows from storm events that result in bankfull flow conditions (typically the 2-year storm, which controls the form of the stream channel), damaging effects to the channel from increased runoff due to urbanization can be reduced.

Either of the following two methods can be used to satisfy the stream channel protection criterion. Both rely on "over-control" of the two-year frequency design storm:

- *Control the 2-year, 24-hour post-development peak flow rate to 50 percent of the 2-year, 24-hour pre-development level or*
- *Control the 2-year, 24-hour post-development peak flow rate to the 1-year, 24-hour pre-development level*

There are several practical limitations on the application of the stream channel protection criterion. For sites having less than one acre of impervious cover, the size of the orifice or weir required for extended detention becomes too small (approximately 1 inch in diameter) to effectively operate without clogging. In addition, channel protection is generally not required where sites discharge to a large receiving water body (Brown and Caraco, 2001). Therefore, the channel protection criterion does not apply under the following conditions:

- *The entire channel protection volume is recharged to groundwater*
- *Sites less than or equal to one acre of impervious cover*
- *The site discharges to a large river (fourth order or greater), lake, estuary, or tidal water where the development area is less than 5 percent of the watershed area upstream of the development site unless known water quality problems exist in the receiving waters. Stream order indicates the relative size of a stream based on Strahler's (1957) method. Streams with no tributaries are first order streams, represented as the start of a solid line on a 1:24,000 USGS Quadrangle Sheet. A second order stream is formed at the confluence of two first order streams, and so on.*

Rationale

A number of design criteria have been developed for the purpose of stream channel protection. The earliest and most common method relied on control of post-development peak flows associated with the 2-year, 24-hour storm event to pre-development levels based on the assumption that bankfull discharge for most streams has a recurrence interval of between 1 and 2 years (Leopold, et al., 1964 and Leopold, 1994). More recent research indicates that this method does not adequately protect stream channels from downstream erosion and may actually contribute to erosion since banks are exposed to a longer duration of erosive bankfull and sub-bankfull events (MacRae, 1993 and 1996, McCuen and Moglen, 1988).

The two-year "over-control" methods recommended above were developed as a modification of the original two-year control approach to provide additional protection. These methods require larger detention volumes than the traditional two-year approach, but reduce the duration of bankfull flows. More recent research has shown that extended detention of the 1-year, 24-hour storm event and a method referred to as Distributed Runoff Control (DRC) potentially provide the highest level of stream channel protection. In the extended detention method, the runoff volume generated by the 1-year, 24-hour rainfall (2.6 to 2.7 inches in Connecticut) is captured and gradually released over a 24-hour period to control erosive velocities in downstream channels. However, this method results in extremely large detention storage requirements (comparable to the storage volume required for 10-year peak discharge control), and the incremental benefits of this approach over the two-year over-control approach are undocumented. The DRC method involves detailed field assessments and hydraulic/hydrologic modeling to determine hydraulic stress and erosion potential of stream banks. This level of detailed, site-specific analysis is not warranted for use as a general stream channel protection criterion.

7.6.2 Conveyance Protection

Description

The conveyance systems to, from, and through stormwater management facilities should be designed based on the peak discharge rate for the 10-year, 24-hour storm. This criterion is designed to prevent erosive flows within internal and external conveyance systems associated with stormwater treatment practices such as channels, ditches, berms, overflow channels, and outfalls. The local review authority may require the use of larger magnitude design storms for conveyance systems associated with stormwater treatment practices.

Rationale

This criterion is generally consistent with storm drainage system design in Connecticut, including design requirements of most municipalities and the Connecticut Department of Transportation.

7.6.3 Peak Runoff Attenuation

Description

The peak runoff attenuation criterion is designed to address increases in the frequency and magnitude of flooding caused by development. This criterion is intended to control a range of flood conditions, from events that just exceed the bankfull capacity of the stream channel to catastrophic flooding associated with extremely large events. Other objectives include maintaining the boundaries of the pre-development 100-year floodplain and protecting the physical integrity of stormwater management facilities.

The recommended peak runoff attenuation criterion in Connecticut includes control of post-development peak discharge rates from the 10-year, 25-year, and 100-year storms to the corresponding pre-development peak discharge rates, as required by the local review authority. Attention must be given to timing of peak flows. The local review authority may require peak runoff attenuation for additional design storms such as the 1-year, 2-year, 5-year and 50-year, 24-hour events. The local review authority may waive the peak runoff attenuation criterion for sites that discharge to a large river (fourth order or greater), lake, estuary, or tidal waters where the development area is less than 5 percent of the watershed area upstream of the development site.

Rationale

This criterion is generally consistent with storm drainage system design in Connecticut, including design requirements of most municipalities and the Connecticut Department of Transportation.

7.6.4 Emergency Outlet Sizing

Description

The emergency outlets of stormwater management facilities should be designed to safely pass the peak discharge rate associated with the 100-year storm or larger. The emergency outlet should be able to pass the 100-year peak runoff rate, at a minimum, in a controlled manner, without eroding outfalls or downstream conveyances. Emergency outlets constructed in natural ground are generally preferable to constructed embankments. This criterion is applicable to all stormwater management facilities that employ an emergency outlet.

Rationale

This criterion is generally consistent with storm drainage system design in Connecticut, including design requirements of most municipalities and the Connecticut Department of Transportation.

7.6.5 Downstream Analysis

Peak runoff control criteria are typically applied at the immediate downstream boundary of a project area. However, since stormwater management facilities may change the timing of the post-development hydrograph, multiple stormwater treatment practices or detention facilities in a watershed may result in unexpected increases in peak flows at critical downstream locations such as road culverts and areas prone to flooding. This effect is most pronounced for detention structures in the middle to lower third of a watershed. The local review authority may require a downstream analysis to identify potential detrimental effects of proposed stormwater treatment practices and detention facilities on downstream areas.

The downstream analysis should include the following elements:

- *Routing calculations should proceed downstream to a confluence point where the site drainage area represents 10 percent of the total drainage area (i.e., the "10 percent rule")*
- *Calculation of peak flows, velocities, and hydraulic effects at critical downstream locations (stream confluences, culverts, other channel constrictions, and flood-prone areas) to the confluence point where the 10 percent rule applies*
- *The analysis should use an appropriate hydrograph routing method, such as TR-20, to route the pre- and post-development runoff hydrographs from the project site to the downstream critical locations*

The ultimate objective of this analysis is to ensure that proposed projects do not increase post-development peak flows and velocities at critical downstream locations in the watershed. Increases in flow rates and velocities at these locations should be limited to less than 5 percent of the pre-developed condition (NYDEC, 2001) and should not exceed freeboard clearances or allowable velocities.

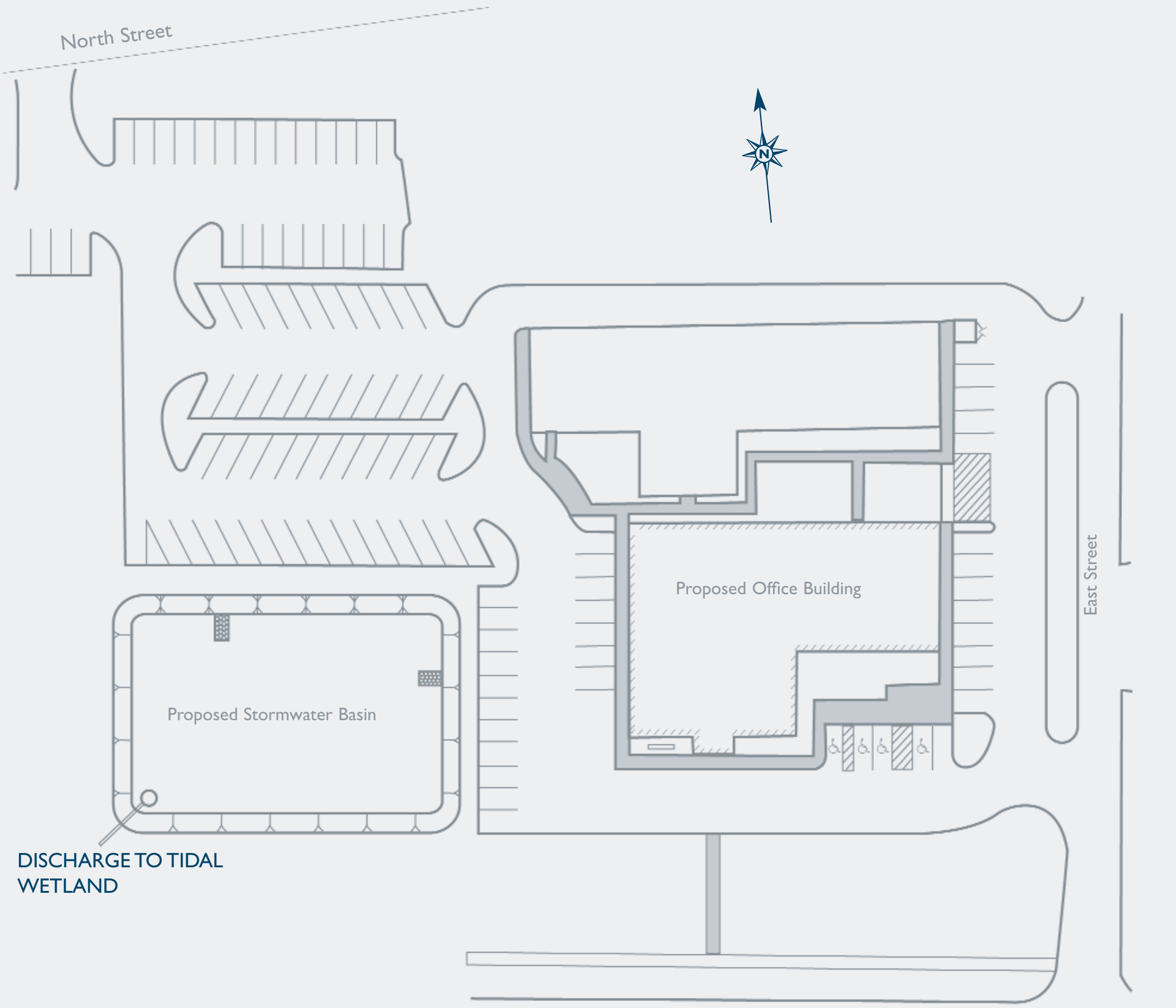
7.7 Sizing Example

The following example illustrates how the various sizing criteria described in this chapter are applied to determine stormwater treatment requirements (required storage volume and hydraulic capacity) for a hypothetical development project.

Old Town Office Building, New London, Connecticut

An office building is proposed on a commercial property in New London, Connecticut. The approximately 2-acre site is characterized by Type B soils. The proposed development consists of approximately 80 percent impervious area (parking lots and buildings), with approximately 20 percent as lawn or undisturbed area. Runoff from the impervious areas is collected and conveyed to a hypothetical stormwater treatment basin located on the southwest portion of the site. Stormwater is discharged from the basin to an adjacent tidal wetland. **Figure 7-1** shows a schematic layout of the proposed development.

Figure 7-1 Sizing Example – Proposed Old Town Office Building



Project Data

Location: New London, CT
Total Drainage Area (A)
Existing = 1.98 Ac; Proposed = 2.40
Impervious Area = 1.92 Ac; or I = 1.92/2.40= 80.0 %
Site Soil Type: "B"
Zoning: Business
Discharge to tidal wetlands

Hydrologic Data

	Pre-Development	Post-Development
CN	82	92
Tc (hr)	0.25	0.17

Source: Fuss & O'Neill, Inc.

1. Water Quality Volume

a. Compute volumetric runoff coefficient, R

$$R = 0.05+0.009(I)$$
$$= 0.05+0.009(80)$$
$$= \underline{0.77}$$

b. Compute water quality volume, WQV

$$WQV = (1")(R)(A)/12$$
$$= (1")(0.77)(2.40)/12$$
$$= \underline{0.15 \text{ ac-ft}}$$

2. Water Quality Flow

Compute the water quality flow (WQF) for off-line stormwater treatment.

a. Compute the runoff depth, Q

$$Q = \frac{[WQV(acre-feet)] \text{ x } [12(inches/foot)]}{Drainage\ Area\ (acres)}$$

$$= \frac{(0.15)\text{x}[12(inches/foot)]}{2.40}$$

$$= \underline{0.77 \text{ in}}$$

b. Compute the NRCS Runoff Curve Number (CN)

$$CN = \frac{1000}{\left[10 + 5P + 10Q - 10(Q^2 + 1.25QP)^{1/2}\right]}$$

$$= \frac{1000}{\left[10 + 5(1) + 10(0.77) - 10\left((0.77)^2 + 1.25\ (0.77)(1)\right)^{1/2}\right]}$$

$$= \underline{98}$$

c. Read initial abstraction, I_a (Table 4-1 in Chapter 4, TR-55)

$I_a = 0.041$

d. Compute I_a/P

$= 0.041/1$

$= \underline{0.041}$

e. Read initial abstraction, q_u (Exhibit 4-11 in Chapter 4, TR-55)

q_u = 580 csm/in (Type III storm)

f. Compute water quality flow (WQF)

$$WQF = (q_u)(A)(Q)$$
$$= (580)(0.004)(0.77)$$
$$= \underline{1.8 \text{ cfs}}$$

3. Groundwater Recharge Volume

Compute the groundwater recharge volume (*GRV*) using the hydrologic soil group approach.

a. Read runoff depth to be recharged, *D* (Table 7-4)
D = 0.25 in

b. Compute net increase in site imperviousness, *I* (proposed) – *I* (existing)
I = 0.80-0.44
= 0.36

c. Compute groundwater recharge volume, *GRV*

$$GRV = \frac{(D)(A)(I)}{12}$$

$$= \frac{(0.25)(2.40)(0.36)}{12}$$

$$= \underline{0.018 \text{ ac-ft}}$$

4. Runoff Capture Volume

Compute the runoff capture volume (*RCV*) since the site discharges stormwater within 500 feet of tidal wetlands.

$$RCV = \frac{(1")(R)(A)}{(12)}$$

$$= \frac{(1")(0.77)(2.40)}{(12)}$$

$$= \underline{0.15 \text{ ac-ft}}$$

5. Stream Channel Protection

Compute the required stream channel protection discharge using both "Two-Year Over-Control" methods recommended in Section 7.6.1.

a. Method-1, control the 2-year, 24-hour post-development flow to 50% of the 2-year, 24-hour pre-development flow

$Q_{2(control)}$ = (0.5) $Q_{2(exist)}$
= (0.5)(2.2)
= 1.1 cfs
$Q_{2(proposed)}$ = 0.9 cfs
$Q_{2(proposed)} < Q_{2(control)}$, meets method-1 criteria

b. Method-2, control the 2-year, 24-hour post-development flow to the 1-year, 24-hour pre-development flow

$Q_{1(exist)}$ = 1.8 cfs
$Q_{1(exist)} > Q_{2(proposed)}$, meets method-2 criteria

6. Conveyance Protection

Site storm drainage conveyance system designed for a 10-yr, 24-hour post-development peak flow, Q10.

Q_{10} = 4.3 cfs

7. *Peak Runoff Attenuation*

From TR-55 peak discharge summary worksheets:

Storm Event	Pre-Development (cfs)	Post Development (cfs)
10-year	4.3	4.0
25-year	5.3	5.2
100-year	6.8	9.8

8. *Emergency Outlet Sizing*

Safe passage of the 100-year storm event under proposed conditions requires passing Q_{100} of 9.8 cfs through the proposed stormwater basin emergency spillway. The spillway is designed to safely convey 9.8 cfs without causing a breach of the stormwater basin that would otherwise damage downstream areas or present a safety risk.

Summary of Sizing Requirements

Criterion	Requirement
Water Quality Volume	0.15 ac-ft
Water Quality Flow	1.8 cfs
Groundwater Recharge Volume	0.018 ac-ft
Runoff Capture Volume	0.15 ac-ft
Stream Channel Protection	0.9 cfs (2-year "over-control")
Conveyance Protection	4.3 cfs (10-year)
Peak Runoff Attenuation	5.3 cfs (25-year)
Emergency Outlet Sizing	9.8 cfs (100-year)

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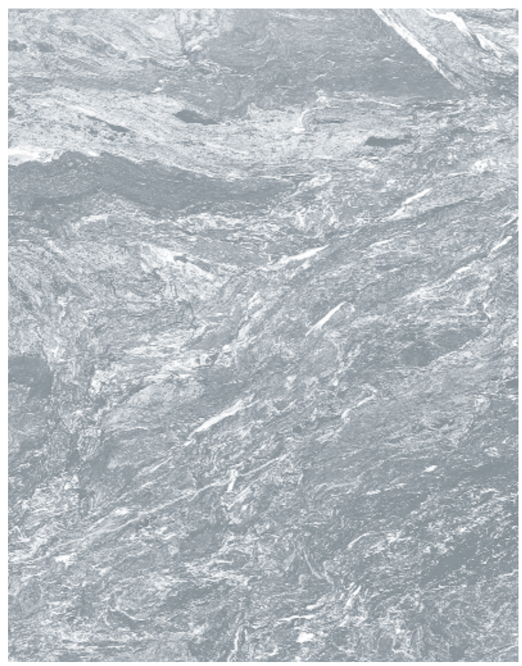
Chapter 8

Selection Criteria for Stormwater Treatment Practices



Volume II: Design

Chapter 8

Selection Criteria for Stormwater Treatment Practices

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8.1 Stormwater Management Effectiveness

No single stormwater treatment practice is appropriate for every site and condition. The applicability of individual practices varies depending upon relatively simple physical constraints, as well as more complicated siting and treatment issues. This chapter addresses criteria to consider when selecting stormwater treatment practices for a particular site.

As discussed in Chapter Two, land development increases the potential for several stormwater related impacts. These impacts are largely a function of altering the natural hydrology at a site and increasing exposure to potential pollutants. Common stormwater impacts related to land development include degraded water quality, increased peak flow rates, increased runoff volume, stream channel erosion, and reduced groundwater recharge.

As discussed in Chapter Seven, stormwater treatment practices can achieve one or more of the following management objectives:

- *Pollutant reduction*
- *Groundwater recharge and runoff volume reduction*
- *Stream channel protection and peak flow control*

Table 8-1 summarizes the relative effectiveness of each stormwater treatment practice in providing these management capabilities. The effectiveness ratings provided in the table should only be used to compare the relative management capabilities of different treatment practices. The ratings should not be used in an absolute sense to quantitatively predict actual field performance.

As described in Chapter Six, there is currently a lack of reliable performance data for stormwater treatment practices in the State of Connecticut. Additionally, the available performance data from past monitoring studies conducted throughout the United States are limited by differences in design, performance goals, site parameters, storm events, flow and pollutant loadings, seasonal variations, monitoring methods, and efficiency calculation methods or simply by the lack of, or inadequate, information. The reliability of pollutant removal efficiencies, which are often cited in guidance documents, is typically poor due to the large degree of uncertainty in the data. Additional performance monitoring using standardized methods and quality control procedures is recommended for new and existing stormwater treatment practices (see Chapter Six) in Connecticut to provide a more useful set of data on the effectiveness of individual stormwater treatment practices, and to better understand the relationship between treatment practice design and performance.

As shown in **Table 8-1**, most of these primary treatment practices are similarly effective at removing sediment, nutrients, and metals. Removal efficiencies are generally highest for sediment, while nutrient and metals removal efficiencies are typically lower. Infiltration systems are generally the most effective practices for removal of bacteria. Designs that incorporate floatable controls or pretreatment are most effective for removal of hydrocarbons. Treatment practices that incorporate biological removal mechanisms, such as constructed wetlands, are also more effective in removing pollutants than systems that strictly rely on gravity or physical separation of particles.

Many of these practices also have limited effectiveness in terms of peak flow control and groundwater recharge. Open bottom basins and dry swales provide some groundwater recharge, but only practices specifically designed as infiltration structures will provide significant levels of groundwater recharge. Many of these practices either have an impermeable bottom or are designed to intercept groundwater and thereby provide little infiltration. Similarly, attenuation of peak flows requires significant available storage capacity to temporarily store runoff as the peak flow is being throttled. Many stormwater treatment practices provide limited storage capacity or detention time and are inadequate as stand-alone flood

Table 8-1 Stormwater Management Effectiveness Criteria

Category	Practice	Pollutant Reduction: Sediment	Total P	Total N	Metals	Hydro Carbons	Bacteria	Ground Water Recharge/ Runoff Volumn Reduction	Stream Channel Protection	Peak Flow Control
Stormwater Ponds	Wet pond	●	●	●	●	●	◐	○	●	●
	Micropool ED pond							◐	●	●
	Wet ED pond							◐	●	●
	Multiple pond system							○	●	●
Stormwater Wetlands	Shallow wetland	●	●	●	◐	●	●	○	●	◐
	ED wetland							○	●	●
	Pond/wetland system							○	●	●
Infiltration Practices	Infiltration trench	●	●	●	●	◐	●	●	◐	○
	Infiltration basin							●	●	◐
Filtering Practices	Surface sand filter	●	●	●	●	●	◐	◐[1]	◐	○
	Underground sand filter							○	○	○
	Perimeter sand filter							○	○	○
	Bioretention							◐[1]	◐	○
Water Quality Swales	Dry swale	●	◐	◐	●	◐	○	◐[1]	○	○
	Wet swale							○	○	○

Notes:
● Effective
◐ Somewhat effective
○ Least effective

[1]If designed as exfilter
ED – Extended Detention

Source: Adapted from Winer, 2000; EPA 1993; and ASCE and Wright Water Engineers, Inc., 2001.

control facilities. Separate facilities for peak flow control are often necessary to augment stormwater treatment practices.

A treatment train approach should be considered when selecting treatment practices for a particular site when faced with several sometimes competing demands. As discussed in Chapter Six, a treatment train consists of a series of management practices each designed to provide targeted pollution control benefits. For example, one practice may be selected for its ability to remove sediments while another may be better suited to remove dissolved pollutants.

8.2 Land Use Factors

Land use, both current and potential future use, should be considered when selecting stormwater treatment practices. Some practices are more "neighbor friendly" than others. Other practices are more land intensive and may be less desirable where space is at a premium. The following land use factors should be considered when selecting stormwater treatment practices.

Rural

Rural areas are typically characterized by low-density development (i.e., few neighbors) and relatively large amounts of available space. Stormwater treatment practices with larger area demands may be easier to locate with appropriate buffers in rural areas. Additionally, typical stormwater pollutants from rural areas include sediments and nutrients, which can be effectively managed by most stormwater treatment practices. As a result, most treatment practices are suitable for rural areas.

Residential

Medium- to high-density residential areas typically have limited space and higher property values compared to rural undeveloped areas. Also, treatment practices in these areas are likely to be located in close proximity to residences. Public safety and nuisance insects are common concerns for treatment practices in residential areas. Stormwater treatment practices with large land requirements or open pools of water may be less desirable in these areas. In some situations, stormwater ponds or other open water practices may be incorporated into the landscape as natural amenities to provide habitat, recreation, and aesthetic value.

Roads and Highways

Roads and highways typically generate high stormwater pollutant loads due to vehicle traffic and winter deicing activities. Sediments, metals, chlorides, and hydrocarbons are the primary pollutants associated with roads and highways. Nitrogen from vehicle exhausts and bacteria are also commonly present in road and highway runoff. As a result, most treatment practices provide some treatment benefit but do not adequately address all of the water quality impacts associated with this land use. In addition, open water and deep pools can also be a safety issue near roads and highways.

Commercial and Industrial Development

Commercial and industrial areas often have more intensive traffic, increased risk of spills, and exposure of materials to precipitation. Pollutants associated with these land uses can vary significantly depending on the nature of activities at each site, although traffic-related pollutants such as sediments, metals, and hydrocarbons are commonly present in runoff from most commercial and industrial sites. These developments may also have more available space for locating stormwater treatment practices.

Ultra-Urban Sites

Ultra-urban sites are the most restrictive in terms of treatment practice selection. These sites are characterized as having little available space or land area, high population density, and a wide range of potential pollutants.

Table 8-2 summarizes the compatibility of stormwater treatment practices with each of the above land uses, considering potential pollutants, public safety, nuisance insects, and land availability.

Table 8-2 Land Use Selection Criteria

Category	Practice	Rural	Residential	Roads and Highways	Commercial/ Industrial	Ultra Urban[3]
Stormwater Pond	Wet pond	●	○	●	●[2]	○
	Micropool extended detention pond	●	◐	●	●[2]	○
	Wet extended detention pond	●	◐	●	●[2]	○
	Multiple pond system	●	○	◐	●[2]	○
Stormwater Wetlands	Shallow wetland	●	○	●	●[2]	○
	Extended detention wetland	●	○	●	●[2]	○
	Pond/wetland system	●	◐	◐	◐[2]	○
Infiltration Practices	Infiltration trench	◐	◐	◐	◐	○
	Infiltration basin	●	◐	●	●	○
Filtering Practices	Surface sand filter	◐	●	●	●[1]	○
	Underground sand filter	○	◐	●	●	●
	Perimeter sand filter	○	○	○	◐	◐
	Bioretention	◐	◐	●	●[1]	◐
Water Quality Swales	Dry swale	●	●	●	◐[1]	○
	Wet swale	●	◐	●	◐	○

Notes: ● Appropriate
◐ Somewhat appropriate
○ Least appropriate

[1]If not designed to infiltrate
[2]May require pond liner
[3]Secondary treatment practices and stormwater treatment trains are typically more appropriate for Ultra Urban land uses

Source: Adapted from NYDEC, 2001.

8.3 Physical/Site Feasibility Factors

Physical site constraints can also dictate the feasibility of specific stormwater treatment practices. These physical constraints can either make the installation of a particular treatment practice too costly or result in reduced or ineffective operation. While every site has its own individual characteristics that need to be evaluated, the five most common physical constraints that need to be considered are:

- *Infiltration capacity*
- *Seasonally high groundwater (water table)*
- *Drainage area*
- *Slope*
- *Required hydraulic head*

These factors are discussed in general terms below. Chapter Eleven contains additional information on physical feasibility and siting considerations for individual treatment practices.

Infiltration Capacity

Infiltration practices are highly dependent on the infiltration capacity of the underlying soils. Low soil infiltration capacity requires structures with larger infiltration surface area and storage capacity to account for slower infiltration rates. Higher soil infiltration rates allow for smaller infiltration structures. Accurate field measurements of infiltration rates are critical for the successful design and implementation of stormwater treatment practices that rely on infiltration of stormwater to underlying soils.

In Connecticut, the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) has developed soil suitability rankings for various types of stormwater management practices, including infiltration trenches, underground infiltration galleries, stormwater wetlands, and stormwater ponds. The soil suitability designations are intended to facilitate proper selection and siting of stormwater controls and are based upon NRCS soil survey soil properties and landscape criteria. The information can be used to generate soil suitability maps for a town, watershed, or other designation. Soils are rated for each practice (suitable, fair, or good), and the specific limitations (slow infiltration, for example) are provided. This tool is intended to be used for initial screening of stormwater treatment practices and does not eliminate the need for on-site evaluation of soil characteristics for design purposes. Additional information on this program can be obtained from the Connecticut USDA NRCS (see Additional Information Sources at the end of this chapter).

Water Table

An elevated water table poses several design issues. The primary issue is the loss of storage and retention capacity in unlined treatment structures. If seasonally high groundwater exists above the bottom of an unlined pond or basin, groundwater will drain into the structure and fill or displace volume that may have been intended for retention. If a treatment practice is constructed below the seasonally high water table, the loss of storage capacity should be accounted for in the design, or engineering controls such as liners and/or underdrains should be considered.

An elevated water table may be advantageous for some treatment practices where a permanent pool of water is desired, such as stormwater wetlands. However, small separation between the bottom of a treatment structure and the water table may result in inadequate pollutant attenuation and treatment in the unsaturated zone. The potential for groundwater pollution due to stormwater infiltration is an important consideration in the design of stormwater treatment practices. Engineering controls such as impermeable liners may be required in these circumstances.

Buoyancy of structures installed below the water table is another issue related to a high water table. Below the water table, buoyancy is calculated as the weight of water displaced (i.e., the volume of the structure below the water table multiplied by the unit weight of fresh water or 62.4 pounds per cubic foot). The upward buoyant force may be large enough to displace a structure, sometimes out of the ground. Engineering controls typically consist of anchors, such as connecting the structure to an appropriately sized concrete pad to provide adequate weight to offset buoyant forces.

Field determination of seasonally high groundwater is required for the successful design and implementation of most stormwater treatment practices.

Drainage Area

The efficiency of most treatment practices decreases with increasing drainage area and volume of stormwater runoff. An increased hydraulic load can increase velocities and reduce detention time in a treatment structure. The size of some practices can be increased to address the issues associated with an increased hydraulic load. Other treatment practices are better suited to smaller drainage areas and smaller hydraulic loads. One approach to improving the efficiency of practices serving larger drainage areas is to construct diversion structures for treatment of the Water Quality Volume, while larger flows or volumes are bypassed around the treatment system.

Slope

The ground slope at and immediately adjacent to the location of a treatment practice, as well as the slope of the contributing watershed and drainage flow paths, are important factors in determining the feasibility of treatment controls. Most stormwater treatment practices are sensitive to the local terrain slope. For example, swales and infiltration basins cannot be used in steep terrain, while others such as stormwater ponds and filtering practices can be adapted to most terrain. The slope of the contributing drainage area or watershed can influence erosion and sediment loads to the treatment system. Many stormwater treatment practices are not recommended for sites with significant sediment loads without suitable pretreatment.

Required Head

Several practices, such as stormwater filtering systems, require larger hydraulic head for gravity flow to and through the system. For example, if only four feet of grade exists on a site between the most hydraulically remote point on the site and the invert elevation of the discharge, a treatment practice that requires five feet of head would not be feasible.

Table 8-3 summarizes the physical feasibility criteria discussed above.

8.4 Downstream Resources

While all sites should provide at least a minimum level of protection, stormwater treatment practices should be tailored not only to the conditions that exist at a particular site, but also to the downstream resources that could be impacted by stormwater discharges from the site. As a result, the following downstream resources should be considered in the treatment practice selection process.

Sensitive Watercourses

Streams, brooks, and rivers that are classified by DEP as Class A (fishable, swimmable, and potential drinking water), as well as their tributary watercourses and wetlands, are high quality resources that warrant a high degree of protection. Toxic pollutants such as metals and soluble organics, as well as other contaminants such as bacteria, are the primary concern for these waterbodies. Sensitive cold water fisheries, including Class B waters or managed stocked streams, could also be adversely impacted by stormwater runoff with elevated temperatures. In addition, the rate and volume of stormwater discharges from new developments are especially critical to these systems, as they could impact the flood carrying capacity of the watercourse and increase the potential for channel erosion.

Water Supply Aquifers

Groundwater is a major source of drinking water in Connecticut for residences that rely on small private wells and larger water distributors. This applies to both water supply aquifers and Class GA and GAA groundwaters as defined by DEP. In addition, groundwater is the source of dry weather flows (baseflow) in watercourses, which is critical for maintaining suitable habitat. As a result, it is important to maintain groundwater recharge, and to maintain a high quality recharge to groundwater in water supply aquifers and Class GA and GAA waters.

Lakes and Ponds

Lakes and ponds are especially sensitive to sediment and nutrient loadings. Excess sediments and nutrients are the cause of algal blooms in these surface waters, leading to eutrophication and degradation. These conditions often result in costly dredging and rehabilitation projects. In fresh water systems, phosphorus is typically the limiting nutrient, that is, much less phosphorus is needed compared to other nutrients such as nitrogen to create eutrophic conditions. As a result, treatment practices should focus on nutrient removal, particularly phosphorus, for stormwater discharges to lakes and ponds, and watercourses that feed lakes and ponds. Control of phosphorus is also directly related to the control of iron. Certain iron compounds such as ferric iron often have a high scavenging coefficient for metals. Thus, control of phosphorus may have ancillary benefits in the control of metals.

Surface Water Drinking Supplies

Surface waters that supply drinking water are especially susceptible to contamination by bacteria and other pathogens. Other contaminants-of-concern may be defined for specific water supply systems by the owner/operator or the State Department of Health. Treatment practices for sites within drinking water supply watersheds should target these potential contaminants. The Public Health Code also requires a 100-foot separation distance between drainage or treatment practice outlets and public water supply tributaries. Site designs within public water supply watersheds are encouraged to maximize absorption of pollutants by the soil and vegetation.

Estuary/Coastal

Coastal or estuary areas are more sensitive to nitrogen loadings than fresh water systems. In salt water systems, nitrogen tends to be the limiting nutrient as opposed to phosphorus. Bacteria are also a concern given the sensitivity of public swimming areas and shellfish beds to bacterial loadings.

Table 8-4 summarizes limitations and engineering considerations for stormwater treatment practices based on downstream resources and the receiving environment.

Table 8-3 Physical Feasibility Criteria

Category	Practice	Soil Infiltration Capacity	Seasonally High Water Table	Drainage Area (acres)	Slope	Required Head
Stormwater Ponds	Micropool ED pond	USDA Hydrologic Soil Group A and B soils may require pond liner unless groundwater intercepted	Construct below water table. Construct liner for sites with higher potential pollutant loads or water supply aquifers.	10 min[1]	15% max	4 to 8 ft
	Wet Pond			25 min[1]		
	Wet ED pond			1-5 max[2] (pocket pond)		
	Multiple pond system					
Stormwater Wetlands	Shallow wetland	USDA Hydrologic Soil Group A and B soils may require pond liner unless groundwater intercepted	Construct below water table. Use liner for sites with higher potential pollutant loads or water supply aquifers	10 min	8% max	2 to 5 ft
	ED wetland			5 max[2] (pocket wetland)		
	Pond/wetland system					
Infiltration Practices	Infiltration trench	Min field measured infiltration rate 0.3 in/hr. Max infiltration rate 5.0 in/hr. Pretreatment required over 3.0 in/hr	Bottom of facility 3 feet above seasonally high water table	2 max[2]	15% max	1 ft
	Infiltration basin			10 max[2]		3 ft
Filtering Practices	Surface sand filter	Unrestricted	Underdrain for unlined system 2 feet above seasonally high water table	25 max[2]	6% max	5 ft
	Underground sand filter			10 max[2]		5 to 7 ft
	Perimeter sand filter			2 max[2]		2 to 3 ft
	Bioretention			5 max[2]		2 to 5 ft
Water Quality Swales	Dry Swale	Unrestricted	Swale bottom 2 to 4 feet above seasonally high water table	5 max[2]	5% max	3 to 5 ft
	Wet Swale	Unrestricted	At or below seasonally high water table	5 max[2]		<1 ft

Notes: [1]Unless adequate water balance
[2]Drainage area can be larger if appropriately designed
ED – Extended Detention

Source: Adapted from NYDEC, 2001.

Table 8-4 Downstream Resource Selection Criteria (A)

Category	Practice	Sensitive Watercourses	Water Supply Aquifers	Lakes and Ponds
Stormwater Ponds	Micropool extended detention pond	Restrict in-stream practices Minimize permanent pool area, and encourage shading to reduce thermal impacts	Require liner if USDA Hydrologic Soil Group A soils are present or <2 ft separation to seasonally high groundwater	Encourage the use of a large permanent pool to increase residence time to improve phosphorus removal
	Wet pond			
	Wet extended detention pond			
	Multiple pond system			
Stormwater Wetlands	Shallow wetland	Restrict use or utilize shading	Pretreat runoff from land uses or sites with the potential for high pollutant loadings	
	Extended detention wetland			
	Pond/wetland system			
Infiltration Practices	Infiltration trench	Encourage use to maximize groundwater recharge Combine with a detention facility to provide flood control and channel protection	Provide 100 ft horizontal separation distance from wells and 3 ft vertical distance from the seasonally high water table, 4 ft from bedrock Pretreat runoff from all land uses prior to infiltration	OK, provides high phosphorus removal
	Infiltration basin			
Filtering Practices	Surface sand filter	Combine with a detention facility to provide flood control and channel protection	Excellent pretreatment for infiltration or open channel practices	OK, but designs with a submerged filter bed may result in phosphorus release
	Underground sand filter			
	Perimeter sand filter			
	Bioretention			
Water Quality Swales	Dry swale	Combine with a detention facility to provide flood control and channel protection	OK, but pretreat runoff from land uses or sites with the potential for high pollutant loadings	OK, moderate phosphorus removal
	Wet swale			

Table 8-4 Downstream Resource Selection Criteria (B)

Category	Practice	Surface Water Drinking Supplies	Estuary/ Coastal
Stormwater Ponds	Micropool extended detention pond Wet pond Wet extended detention pond Multiple pond system	Encourage the use of a large permanent pool to improve phosphorus removal Promote long detention times to encourage pollutant removal Provide 100 ft separation distance from outlet to public water supply tributary	Encourage long detention times to promote pollutant removal Consider tidal elevations More effective for removal of inorganic nitrogen and ammonia; less effective for organic nitrogen removal
Stormwater Wetlands	Shallow wetland Extended detention wetland Pond/wetland system	Encourage the use of a large permanent pool to improve phosphorus removal Promote long detention times to encourage bacteria removal Provide 100 ft separation distance from outlet to public water supply tributary	Encourage long detention times to promote pollutant removal Consider tidal elevations
Infiltration Practices	Infiltration trench Infiltration basin	Provide 4 ft separation distance to bedrock and 3 ft to seasonally high water table Pretreat runoff prior to infiltration practices	OK, but provide 3 ft separation distance to seasonally high groundwater
Filtering Practices	Surface sand filter Underground sand filter Perimeter sand filter Bioretention	Excellent pretreatment for infiltration or open channel practices Moderate to high bacteria removal Provide 100 ft separation distance from outlet to public water supply tributary	Moderate to high bacteria removal Designs with a submerged filter bed appear to provide high nitrogen removal
Water Quality Swales	Dry swale Wet swale	Pretreat runoff Minimal bacteria removal Provide 100 ft. separation distance from outlet to public water supply tributary	Pretreat runoff Minimal bacteria removal

Source (Tables 8-4 A and B): Adapted from NYDEC, 2001.

8.5 Maintenance Factors

Regular maintenance is required for the successful long-term operation of any stormwater treatment practice. Accumulated sediment and floatables reduce pollutant removal efficiencies and increase the potential for resuspension as well as sediment reflux. Accumulated debris can also impact hydraulic performance. Some treatment practices require more intensive or more frequent maintenance in order to function as designed. For example, the filter bed of a sand filter needs to be replaced when clogged, and stormwater wetlands need to be "harvested" periodically.

Table 8-5 summarizes the maintenance requirements for stormwater treatment practices. Maintenance sensitivity is a measure of a practice's susceptibility to reduced performance if not adequately maintained.

8.6 Winter Operation

In Connecticut, the effects of winter conditions (cold temperatures, snow, ice, etc.) on stormwater treatment practice performance are important considerations. While there may be fewer runoff events during winter months, snow and ice may significantly impact the operation of some treatment practices during winter

Table 8-5 Maintenance Criteria

Category	Practice	Maintenance Sensitivity	Inspections	Sediment Removal	Other
Stormwater Ponds	Micropool extended detention pond	❍	❍	◍	Aging ponds become ineffective and may become pollutant sources in some cases; decadal evaluations are considered minimal; more frequent dredging may be required in developing watersheds with significant sediment loads
	Wet pond	❍	❍	◍	
	Wet extended detention pond	❍	❍	◍	
	Multiple pond system	❍	❍	◍	
Stormwater Wetlands	Shallow wetland	◍	◍	●	Requires periodic harvesting to maximize nutrient and metals removal
	Extended detention wetland	❍	❍	●	
	Pond/wetland system	❍	❍	●	
Infiltration Practices	Infiltration trench	●	●	●	Frequent sediment/debris removal required for proper performance
	Infiltration basin	●	●	●	
Filtering Practices	Surface sand filter	●	●	●	Periodic removal and replacement of media is required
	Underground sand filter	●	●	●	
	Perimeter sand filter	●	●	●	
	Bioretention	●	●	●	
Water Quality Swales	Dry Swale	❍	❍	❍	Sediment removal may damage swale
	Wet Swale	❍	❍	❍	

Notes: ● Significant ◍ Moderately Significant ❍ Least Significant

Source: Adapted from Watershed Management Institute (WMI), 1997.

rain events and periods of snowmelt. Some of these potential impacts are:

Pipe Freezing: Most treatment practices, with the exception of vegetative filter strips, rely on some form of inlet piping, and may also have an outlet or underdrain pipe. Frozen pipes can crack due to ice expansion, creating a maintenance or replacement burden. In addition, pipe freezing reduces the hydraulic capacity of the system, thereby limiting pollutant removal and creating the potential for flooding (Center for Watershed Protection, 1997).

Ice Formation on the Permanent Pool: Ice cover on the permanent pool causes two problems. First, the treatment pool's volume is reduced. Second, since the permanent pool is frozen, it acts as an impermeable surface. Runoff entering an ice-covered pond can follow two possible routes, neither of which provides sufficient pollutant removal. In the first, runoff is forced under the ice, causing scouring of bottom sediments. In the second, runoff flows over the top of the ice, receiving little or no treatment. Sediment that settles on top of the ice can easily be resuspended by subsequent runoff events (Center for Watershed Protection, 1997).

Reduced Biological Activity: Many stormwater treatment practices rely on biological mechanisms to help reduce pollutants, especially nutrients and organic matter. For example, wetland systems rely on plant uptake of nutrients and the activity of microbes at the soil/root zone interface to break down pollutants. During cold temperatures (below 40°F), photosynthetic and microbial activity is sharply reduced when plants are dormant during the non-growing season, limiting these pollutant removal pathways (Center for Watershed Protection, 1997).

Reduced Soil Infiltration: The rate of infiltration in frozen soils is limited, especially when ice lenses form (Center for Watershed Protection, 1997). This reduced infiltration significantly impacts the operation of infiltration practices and other treatment systems that rely on infiltration of stormwater into the soil.

Table 8-6 summarizes winter operation and cold weather considerations for stormwater treatment practices. Chapter Eleven includes design guidance for mitigating the potential effects of cold weather on treatment practice operation and performance.

8.7 Nuisance Insects and Vectors

Some stormwater treatment practices can provide breeding habitat for mosquitoes, ticks, fleas, and other vectors (organisms that can transmit pathogens that can cause an infectious disease such as West Nile fever, Lyme disease, and St. Louis encephalitis). Mosquitoes are one of the most prevalent nuisance insects, as well as vectors of West Nile fever and Eastern Equine Encephalitis virus, in Connecticut, and therefore are the focus of many municipal control programs.

The approximately 48 species of mosquitoes in Connecticut can be broadly grouped into two categories: those that lay eggs directly on a stagnant water surface ("surface water mosquitoes"), and those that lay eggs on a moist substrate (mud, leaf litter) and hatch at a later date when flooded by rain or tides ("floodwater mosquitoes"). The eggs of floodwater species can lie dormant for several years until conditions are right for hatching. Usually, however, the eggs will survive over winter and hatch with the spring thaw. Eggs of "surface water" mosquitoes do not survive over the winter. The adults survive during the winter in caves, basements, and other similar environments and emerge with warmer weather. The rate of development (from hatching to emergence) is controlled by photoperiod (length of day) and water temperature. In the spring, this may take up to a month and a half. In the summer, it may take as little as 1 to 2 weeks. Generally speaking, relative to stormwater basins and other treatment practices, there is the potential for mosquito breeding if water is allowed to stand or stagnate, in the absence of predators, for more than 7 to 10 days in the summer (Roger Wolfe, Mosquito Management Coordinator, DEP 2003).

When located in residential and urban areas, stormwater treatment practices that hold water for an extended period (longer than 7 to 10 days) have the potential to become new sources of mosquito habitat or aggravate existing mosquito problems. According to national studies conducted by the California Department of Health Services and the California Department of Transportation (1998), stormwater treatment practices that maintain permanent sources of standing water in sumps, basins (wetlands, perimeter sand filters), or wet swales provide habitat for immature mosquitoes and frequently support relatively larger mosquito populations. Catch basins with sumps provide ideal mosquito breeding conditions (particularly species of the genus Culex): stagnant, organically rich water in a shaded and humid environment devoid of predators. In contrast, stormwater treatment practices designed to drain more rapidly (dry swales, filter strips, extended detention structures, and infiltration structures) provide less suitable habitats and rarely harbor mosquitoes. Treatment practices that employ a larger permanent body of open water (i.e., ponds) generally pose lower risk of mosquito breeding since larger open bodies of water are not conducive to mosquito egg laying and, unless extremely polluted, a pond community structure will

Table 8-6 Winter and Cold Weather Operation Criteria

Category	Practice	Pipe Freezing	Ice Formations	Reduced Biological Activity	Reduced Soil Infiltration
Stormwater Ponds	Micropool extended detention pond	●	●	◍	❍
	Wet pond	●	●	◍	❍
	Wet extended detention pond	●	●	◍	❍
	Multiple pond system	●	●	◍	❍
Stormwater Wetlands	Shallow wetland	●	●	●	❍
	Extended detention wetland	●	●	●	❍
	Pond/wetland system	●	●	●	❍
Infiltration Practices	Infiltration trench	❍	❍	❍	●
	Infiltration basin	❍	❍	❍	●
Filtering Practices	Surface sand filter	◍	◍	❍	●
	Underground sand filter	❍	❍	❍	❍
	Perimeter sand filter	◍	◍	❍	❍
	Bioretention	◍	◍	❍	◍
Water Quality Swales	Dry Swale	❍	❍	◍	◍
	Wet Swale	❍	◍	◍	❍

Notes: ● Significant
◍ Moderately Significant
❍ Least Significant

Source: Adapted from Center for Watershed Protection, 1997.

support a natural predator population. Improperly maintained structures can also result in sediment and debris accumulation that can contribute to conditions of prolonged standing water.

Proper siting, design, and maintenance of stormwater treatment practices are important factors in minimizing the potential for these structures to become mosquito-breeding areas. Stormwater ponds, wetlands, and other treatment practices that maintain standing water for a prolonged period should be carefully considered and designed in residential, commercial, and other urban areas where mosquito control is a concern. Key design considerations for mosquito control include:

- *Limiting water retention or draining time to 5 days or less (based on a 7 to 10 day summer breeding period and a factor of safety). Structures designed with sumps or basins that retain water permanently or longer than 5 days should be sealed completely to prevent entry of adult mosquitoes.*
- *Maintaining pond and wetland water quality sufficient to support mosquito-feeding fish and other aquatic predators. Stormwater ponds and wetlands often develop mini-ecosystems where birds, frogs, and other insects feed, many of which are natural predators of mosquitoes and other nuisance insects. Ponds can also be stocked with fish native to Connecticut that feed on mosquito larvae such as banded killfish, golden shiners, and pumpkinseed sunfish. The DEP Inland Fisheries Division should be consulted regarding species selection and permitting requirements. A liberation permit is required to introduce these and other fish into ponds and other water bodies in Connecticut. Other natural predators of mosquitoes such as dragonfly nymphs can also be used.*
- *Maintaining permanent pond water depths in excess of 4 feet to preclude invasive emergent vegetation such as cattails. Dense emergent vegetation provides mosquito larvae with refuge from predators.*
- *Designing ponds to allow for easy dewatering of the basin when necessary.*
- *Providing sufficient slope on basin floors and swales for adequate drainage.*
- *Ensuring sufficient separation distance to the seasonal high groundwater table for infiltration structures.*
- *Sealing potential mosquito entry points in underground stormwater treatment devices (adult female mosquitoes can use openings as small as 1/16 inch to access water for egg laying).*

Chapter Eleven includes additional design guidance to avoid or reduce mosquito-breeding problems for individual treatment practice categories.

8.8 Natural Wetlands and Vernal Pools

Careful consideration should be given to the selection, design, and location of stormwater treatment practices on or near sites with natural wetlands and vernal pools. Conventional stormwater management techniques often have adverse impacts on biodiversity. Wildlife species that migrate seasonally between forested upland habitats and vernal pools (and other small wetlands) are particularly susceptible (Calhoun and Klemens 2002). Populations of turtles, snakes, small mammals, frogs, and salamanders often decline in areas with intensive stormwater management measures. Curb and catch-basin systems, particularly in combination with hydrodynamic separators, can intercept, trap, and kill amphibians and other small animals crossing roads. Stormwater wetlands and ponds that are placed near vernal pools can also threaten pool-breeding amphibian populations. Stormwater ponds and wetlands can serve as "decoy" pools, intercepting amphibians as they migrate in spring to their vernal pool breeding habitats. Amphibians often deposit their eggs in these artificial wetlands. The eggs rarely survive due to sediment and pollutant loads, which are concentrated in these stormwater treatment systems. Fluctuations in water quality, water quantity, and temperature within these decoy wetlands can also cause reproductive failure. Many vernal pool species are extremely sensitive to hydroperiod (duration of flooding). Stormwater management can de-water (or shorten the hydroperiod) vernal pools. This impacts species that require longer hydroperiods such as marbled salamanders. Stormwater management can also increase the hydroperiod of vernal pools, impacting species that require shorter hydroperiods (e.g., fairy shrimp). In addition, constructed wetlands tend to support highly adaptable, widespread, "weedy" species (e.g., bullfrogs or green frogs), which prey upon, or successfully out-compete, vernal pool-breeding amphibians.

Stormwater ponds and wetlands should be located at least 750 feet from a vernal pool and should not be sited between vernal pools or in areas that are primary amphibian overland migration routes, if known (Calhoun and Klemens 2002). Using natural wetlands as stormwater treatment practices is also highly undesirable. Increases in pollutants, sediments, and "flashiness" of the system degrade the wetland and result in a reduction habitat complexity, leading to reductions in biodiversity. In general, stormwater runoff to vernal pools should be maintained at pre-construction levels to avoid increases ordecreases in water levels and hydroperiod. Chapter Eleven contains additional design guidance to avoid impacts to natural wetlands and vernal pools.

Additional Information Sources

U.S. Department of Agriculture (USDA). Natural Resources Conservation Service (NRCS). 2002 (draft). *Soil Suitability for Stormwater Management Practices*. URL: http://www.ct.nrcs.usda.gov. Contact: Kipen Kolesinskas, State Soil Scientist, 344 Merrow Road, Tolland, CT 06084-3917, (860) 871-4047.

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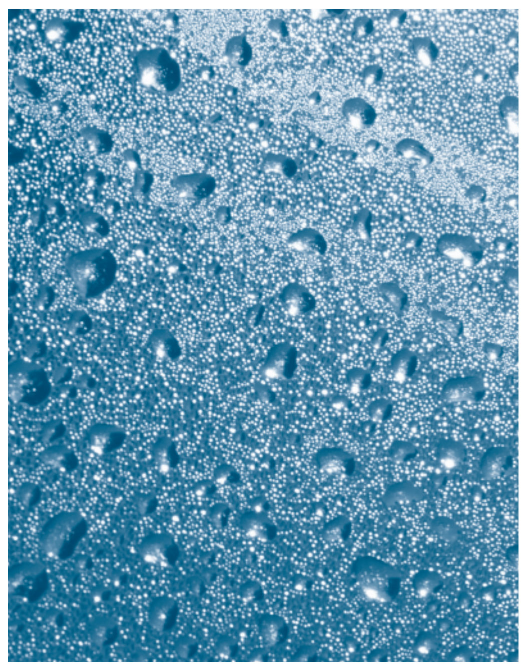
Chapter 9
Developing a Site Stormwater Management Plan



Volume II: Design

Chapter 9

Developing a Site Stormwater Management Plan

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9.1 Plan Development

Stormwater management plans should be developed for all new and redevelopment projects, including phased developments, that meet any of the following criteria:

- *Any development resulting in the disturbance of greater than or equal to one acre of land*
- *Residential development consisting of 5 or more dwelling units*
- *Residential development consisting of fewer than 5 dwelling units involving construction of a new road or reconstruction of an existing road*
- *Residential development consisting of fewer than 5 dwelling units where imperviousness of the site after construction exceeds 30 percent*
- *Stormwater discharge to wetlands/watercourses*
- *New stormwater discharges located less than 500 feet from tidal wetlands*
- *Land uses or facilities with potential for higher pollutant loadings (see Chapter Seven)*
- *Industrial and commercial development projects which result in 10,000 sq. ft. or greater of impervious surface. (Industrial and commercial activities requiring authorization under the DEP* General Permit for the Discharge of Stormwater Associated with Industrial Activity or General Permit for the Discharge of Stormwater Associated with Commercial Activity *have specific Stormwater Management Plan requirements which focus on source controls and pollution prevention.)*
- *New highway, road, and street construction*
- *Modifications to existing storm drainage systems*

These types of projects are also subject to the hydrologic sizing criteria described in Chapter Seven of this Manual.

While this Manual describes the selection and design of a wide range of stormwater treatment practices, it is important that the designer effectively communicates their rationale, design, and maintenance requirements to several audiences including the facility owner, regulatory reviewers, and maintenance personnel. This is critical so that all parties fully understand the need for and the future operation of the treatment practices, and so that the selection of the specified practice is appropriate.

A site stormwater management plan describes the potential water quality and quantity impacts associated with a development project both during and after construction. A stormwater management plan also identifies selected source controls and treatment practices to address those potential impacts, the engineering design of the treatment practices, and maintenance requirements for proper performance of the selected practices.

9.2 Plan Content

A stormwater management plan should include source controls for potential sources of stormwater runoff pollution and treatment controls for stormwater discharges. In addition, any supporting documentation, including calculations, engineering details, or reports, should be provided to illustrate the proposed development's compliance with applicable federal, state, and local regulations, and the design guidelines of this Manual. Professionals (engineers, surveyors, landscape architects, etc.) must affix their seal and dated signature to all plans and documents prepared by them or under their direct supervision.

The major elements of a stormwater management plan include:

- *Applicant/Site Information*
- *Project Narrative*
- *Calculations*

- *Design Drawings and Specifications*
- *Construction Erosion and Sedimentation Controls*
- *Supporting Documents and Studies*
- *Other Required Permits*
- *Operation and Maintenance*

Each of these elements is described further in the following sections. **Appendix D** contains a checklist that can be used in preparing or reviewing a site stormwater management plan.

9.2.1 Applicant/Site Information

The stormwater management plan should include the following information to clearly identify the applicant and site of the proposed activity:

- *Applicant name, legal address, and telephone/fax numbers*
- *Common address and legal description of the proposed site*
- *Site location or locus map*

9.2.2 Project Narrative

Projects that require a stormwater management plan must include documentation that adequately describes the proposed improvements or alterations to the site. In particular, it is necessary to describe any alterations to surface waters, including wetlands and waterways, removal of vegetation, and earth moving operations. The project scope and objective must identify, in summary, the potential water quality impacts to receiving waters during construction and the post-construction water quality and quantity impacts that may occur as a result of the intended use(s) of the property.

In describing the project, alternative designs or construction methods should be evaluated to address the goal of impact minimization through the use of site design practices such as providing "green" parking areas, and preserving natural buffers or open spaces. The purpose of evaluating project alternatives is to achieve a final design that allows an appropriate, legal use of the property while minimizing impacts to surface water quality caused by stormwater runoff.

The project narrative should consist of:

Project Description and Purpose: Provide a general description of the project in adequate detail such that reviewers will have a sense of the proposed project and potential impacts. This section should describe existing and proposed conditions, including:

- *Natural and manmade features at the site including, at a minimum, wetlands, watercourses, floodplains, and development (roads, buildings, and other structures)*
- *Site topography, drainage patterns, flow paths, and ground cover*
- *Impervious area and runoff coefficient*
- *Site soils as defined by USDA soil surveys including soil names, map unit, erodibility, permeability, depth, texture, and soil structure*
- *Stormwater discharges, including the quality of any existing or proposed stormwater discharges from the site and known sources of pollutants and sediment loadings*
- *Critical areas, buffers, and setbacks established by the local, state, and federal regulatory authorities*
- *Water quality classification of on-site and adjacent water bodies and identification of any on-site or adjacent water bodies included on the Connecticut 303(d) list of impaired waters*

Potential Stormwater Impacts: Describe the project's potential for stormwater impacts affecting water quality, peak flow, and groundwater recharge. The elements that should be included in this section are:

- *Description of all potential pollution sources such as erosive soils, steep slopes, vehicle fueling, vehicle washing, etc.*
- *Identification of the types of anticipated stormwater pollutants and the relative or calculated load of each pollutant*
- *A summary of calculated pre- and post-development peak flows*
- *A summary of calculated pre- and post-development groundwater recharge*

Critical On-site Resources: Describe and identify the locations of on-site resources that could potentially be impacted by stormwater runoff. These resources may include:

- ❍ *Wells*
- ❍ *Aquifers*
- ❍ *Wetlands*
- ❍ *Streams*
- ❍ *Ponds*
- ❍ *Public drinking water supplies*

Critical Off-site Resources: Describe and identify the locations of off-site resources (typically downstream of the site) that could potentially be impacted by stormwater runoff. These resources may include:

- ❍ *Neighboring land uses*
- ❍ *Wells*
- ❍ *Aquifers*
- ❍ *Wetlands*
- ❍ *Streams*
- ❍ *Ponds*
- ❍ *Public drinking water supplies*

Proposed Stormwater Management Practices: Describe the proposed stormwater management practices and why they were selected for the project. Stormwater management practices that should be described in this section are:

- ❍ *Source controls and pollution prevention*
- ❍ *Alternative site planning and design*
- ❍ *Stormwater treatment practices*
- ❍ *Flood control and peak runoff attenuation management practices*

Site Plan: Include a site plan showing, at a minimum, the following existing and proposed features:

- ❍ *Topography, drainage patterns, drainage boundaries, and flow paths*
- ❍ *Locations of stormwater discharges*
- ❍ *Perennial and intermittent streams*
- ❍ *Soil types*
- ❍ *Proposed borehole investigations*
- ❍ *Vegetation and proposed limits of clearing and disturbance*
- ❍ *Resource protection areas such as wetlands, lakes, ponds, and other setbacks (stream buffers, drinking water well setbacks, septic setbacks, etc.)*
- ❍ *Roads, buildings, and other structures*
- ❍ *Utilities and easements*
- ❍ *Temporary and permanent conveyance systems (grass channels, swales, ditches, storm drains, etc.) including grades, dimensions, and direction of flow*
- ❍ *Location of floodplain and floodway limits and relationship of site to upstream and downstream properties and drainage systems*
- ❍ *Location, size, maintenance access, and limits of disturbance of proposed structural stormwater management practices (treatment practices, flood control facilities, stormwater diversion structures, etc.)*
- ❍ *Final landscaping plans for structural stormwater management practices and site revegetation*
- ❍ *Locations of source controls*

Construction Schedule: Describe the anticipated construction schedule, including the construction sequence and any proposed phasing of the project.

9.2.3 Calculations

The stormwater management plan should include calculations to demonstrate that the proposed project satisfies the stormwater management objectives and treatment practice sizing criteria described in Chapter Seven of this Manual.

Pollutant Reduction

Water Quality Volume (WQV): Calculate the design water quality volume (WQV) to be treated by the proposed stormwater treatment practices using the procedures described in Chapter Seven. Design calculations should demonstrate that the proposed stormwater treatment practices meet the required WQV, detention time, and other practice-specific design criteria as described in this Manual.

Water Quality Flow (WQF): Calculate the design water quality flow (WQF), which is the peak flow rate associated with the WQV. The WQF is used to size flow rate-based treatment practices (i.e., manufactured treatment systems such as catch basin inserts, media filters, and hydrodynamic structures), grass drainage channels, and flow diversion structures for off-line treatment practices. The WQF should be calculated using the procedures described in **Appendix B**. The peak flow rates associated with larger design storms should also be evaluated to ensure that stormwater treatment practices could safely convey large storm events while providing the minimum rates of pollutant removal established in this Manual.

Pollutant Loads: At the discretion of the review authority, estimate pollutant loads found in pre- and post-development runoff. One method to determine stormwater pollutant loads for urbanized areas is the Simple Method developed by Schueler (Metropolitan Washington Council of Governments, 1987). This method can be used to estimate stormwater pollutant loads for different land uses, but does not provide an estimate of the base flow pollutant load. However, the Simple Method may be used to calculate the pollutant load associated with storm events.

Groundwater Recharge

Groundwater Recharge Volume (GRV): Calculate the required groundwater recharge volume to maintain pre-development annual groundwater recharge on the site after the site is developed. The GRV should be calculated using the procedures described in Chapter Seven. The GRV calculation should include the average annual groundwater recharge (i.e., stormwater infiltration) provided by the proposed stormwater management practices.

Runoff Capture

Runoff Capture Volume (RCV): For new stormwater discharges located less than 500 feet from brackish and tidal wetlands, which are not fresh-tidal wetlands, calculate the volume of runoff generated by the first inch of rainfall. The design calculations should demonstrate how the proposed stormwater management system would retain or infiltrate this runoff capture volume (RCV). The RCV should be calculated based on the procedures described in Chapter Seven.

Peak Flow Control (Stormwater Quantity)

For new development projects, calculations should be provided to demonstrate that post-development peak flows do not exceed pre-development peak flows for a range of design storms. For redevelopment projects, the bank condition and sensitivity of receiving waters may justify a reduction in peak flows and runoff volume from the site. Achieving a reduction in runoff from a redevelopment project may often be feasible with proper planning and implementation of detention or infiltration practices.

A number of methods and models are available to calculate peak stormwater discharge rates, and the designer must determine the most appropriate method for the project. The following information must be submitted with all stormwater management plans:

Hydrologic and Hydraulic Design Calculations: Calculate the pre-development and post-development peak runoff rates, volumes, and velocities at the site limits. The calculations shall be based on the following 24-hour duration design storm events to satisfy the sizing criteria described in Chapter Seven:

- *Stream Channel Protection: 2-year frequency (“over-control” of 2-year storm)*
- *Conveyance Protection: 10-year frequency*
- *Peak Runoff Attenuation: 10-year, 25-year, and 100-year frequency (and other design storms required by the local review authority)*
- *Emergency Outlet Sizing: safely pass the 100-year frequency or larger storm*

Provide the following information for each of the above design storms for pre-development and post-development conditions:

- *Description of the design storm frequency, intensity, and duration*
- *Watershed map with locations of design points and watershed area (acres) for runoff calculations*
- *Time of concentration (and associated flow paths)*
- *Imperviousness of the entire site and each watershed area*
- *NRCS runoff curve numbers or volumetric runoff coefficients*
- *Peak runoff rates, volumes, and velocities for each watershed area*
- *Hydrograph routing calculations*
- *Culvert capacities*
- *Infiltration rates, where applicable*
- *Dam breach analysis, where applicable*
- *Documentation of sources for all computation methods and field test results*

Downstream Analysis: Improperly placed or sized detention may adversely affect downstream areas by delaying the timing of the peak flows from the site. Delayed peaks can coincide with the upstream peak flow that naturally occurs later as the discharge travels from the upper portions of the watershed. If the site is in the middle to lower third of a watershed and detention is proposed, provide calculations of existing and proposed discharges at any critical downstream points using hydrograph analysis. Critical downstream points may be currently flooded properties or roadways, for example. Routing calculations should proceed downstream to a confluence point where the site drainage area represents 10 percent of the total drainage area (i.e., the "10 percent rule"). The downstream analysis should be performed using the methods described in Chapter Seven.

Drainage Systems and Structures: Provide design calculations for existing and proposed drainage systems and structures at the site. Based on the design storm for those structures, a hydrograph analysis should be used to analyze the storage and discharge for detention structures. Drainage system components should be designed according to the standards outlined in this Manual, as well as other applicable local standards or requirements.

9.2.4 Design Drawings and Specifications

Design drawings and specifications must be prepared by a professional engineer licensed to practice in the State of Connecticut. The format of site plans and drawings should conform to the following:

- *Drawings should be no larger than 24" x 36" and no smaller than 8-1/2" x 11".*
- *Plans and documents should not be pieced together or submitted with handwritten markings. Blue line prints or photocopies of original plans are acceptable.*
- *A scale should be used that adequately presents the detail of the proposed improvements for the project. A maximum scale of 1" = 40' is recommended, however larger scales up to 1" = 100' may be used to represent overall site development plans or for conceptual plans. Profiles and cross-sections should be prepared at a maximum scale of 1" = 4' vertical and 1"=40' horizontal.*
- *Design details including cross-sections, elevation views, and profiles as necessary to allow the proper depiction of the proposed controls for review and permitting and ultimately to allow the proper construction of these controls.*
- *Specifications, which clearly indicate the materials of construction, the specific stormwater control product designations (if applicable), the methods of installation, and reference to applicable material and construction standards.*
- *Plans should contain a title block that includes the project title, location, owner, assessor's map and parcel number of the subject site(s), name of preparer, sheet number, date (with revision date, if applicable), and drawing scale.*
- *Legend defining all symbols depicted on the plans.*
- *A cover sheet with a sheet index for plan sets greater than two sheets. Multiple sheets should contain either match lines or provide an overlap of 1" with information on adjoining plan sheets.*
- *North arrow.*
- *Property boundary of the entire subject property and depicting the parcels, or portions thereof, of abutting land and roadways within one hundred feet of the property boundary.*
- *Locus map of the site prepared at a scale of 1" = 1,000' with a north arrow. The map should adequately show the subject site relative to major roads and natural features, if any.*
- *The seal of a licensed professional should be affixed to all original design plans, calculations, and reports prepared by them or under their direct supervision.*

- *Survey plans should be prepared according to the* Minimum Standards for Surveys and Maps in Connecticut *with the class of survey represented on the plan, and must be stamped by a professional land surveyor. The survey plan should depict topography at contour intervals of two feet, the referenced or assumed elevation datum, two (2) benchmarks on the site within one hundred feet of the proposed construction, the outside limits of disturbances, and any plan references.*

9.2.5 Construction Erosion and Sedimentation Controls

The proposed Erosion and Sedimentation Control Plan should, at a minimum, demonstrate the methods and designs to be utilized during construction and stabilization of the site following completion of construction activity. All proposed erosion and sediment control measures must comply with the *Connecticut Guidelines for Soil Erosion and Sediment Control, DEP Bulletin 34* (Connecticut Council on Soil and Water Conservation and the Connecticut Department of Environmental Protection, 2002). Erosion and sediment control measures must be included on the plans with sufficient detail to facilitate review of the design by regulatory officials, and proper construction of the measures.

9.2.6 Supporting Documents and Studies

Information used in the design of construction and post-construction stormwater controls for the overall site development must be included (or referenced, if appropriate) with reports, plans, or calculations to support the designer's results and conclusion. Pertinent information may include:

- *Soil maps, borings/test pits*
- *Infiltration test results*
- *Groundwater impacts for proposed infiltration structures*
- *Reports on wetlands and other surface waters (including available information such as Maximum Contaminant Levels [MCLs], Total Maximum Daily Loads [TMDLs], 303(d) or 305(b) impaired waters listings, etc.)*
- *Water quality impacts to receiving waters*
- *Impacts on biological populations/ecological communities including fish, wildlife (vertebrates and invertebrates), and vegetation*
- *Flood study/calculations*

9.2.7 Other Required Permits

Approval of a stormwater management plan does not relieve a property owner of the need to obtain other permits or approvals from federal, state, and local regulatory agencies. Stormwater regulatory programs in the state of Connecticut are summarized in Chapter One of this Manual. The stormwater management plan should include evidence of acquisition of all applicable federal, state, and local permits or approvals such as copies of DEP permit registration certificates, local approval letters, etc.

Where appropriate, a grading or building permit should not be issued for any parcel or lot unless a stormwater management plan has been approved or waived. If requirements of federal, state, and local officials vary, the most stringent requirements should be followed.

9.2.8 Operation and Maintenance

Stormwater management plans should describe the procedures, including routine and non-routine maintenance, that are necessary to maintain treatment practices, including vegetation, in good and effective operating conditions. Chapter Eleven of this Manual contains operation and maintenance guidelines and recommendations for individual stormwater treatment practices. Operation and maintenance elements that should be included in the stormwater management plan include:

- *Detailed inspection and maintenance requirements/tasks*
- *Inspection and maintenance schedules*
- *Parties legally responsible for maintenance (name, address, and telephone number)*
- *Provisions for financing of operation and maintenance activities*
- *As-built plans of completed structures*
- *Letter of compliance from the designer*
- *Post-construction documentation to demonstrate compliance with maintenance activities*

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Chapter 10
Stormwater Retrofits

Volume II: Design

Chapter 10 Stormwater Retrofits

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10.1 Introduction

Existing development can be modified to incorporate source controls and structural stormwater treatment practices. Such modifications are commonly referred to as stormwater retrofits. This chapter describes opportunities and techniques for retrofitting existing, developed sites to improve or enhance water quality mitigation functions. This chapter also identifies the conditions for which stormwater retrofits are appropriate, as well as the potential benefits and effectiveness of stormwater retrofits.

10.2 Objectives and Benefits of Stormwater Retrofits

The objective of stormwater retrofitting is to remedy problems associated with, and improve water quality mitigation functions of, older, poorly designed or poorly maintained stormwater management systems. In Connecticut prior to the 1970s, site drainage design did not require stormwater detention for controlling post-development peak flows. As a result, drainage, flooding, and erosion problems are common in many older developed areas of the state. Furthermore, a majority of the stormwater detention facilities throughout the state have been designed to control peak flows, without regard for water quality mitigation. Therefore, many existing stormwater detention basins provide only minimal water quality benefit.

Incorporating stormwater retrofits into existing developed sites or into redevelopment projects can reduce the adverse impacts of uncontrolled stormwater runoff. This can be accomplished through reduction in unnecessary impervious cover, incorporation of small-scale Low Impact Development (LID) management practices, and construction of new or improved structural stormwater treatment practices. One of the primary benefits of stormwater retrofits is the opportunity to combine stormwater quantity and quality controls. Stormwater retrofits can also remedy local nuisance conditions and maintenance problems in older areas, and improve the appearance of existing facilities through landscape amenities and additional vegetation.

10.3 When is Retrofitting Appropriate?

Site constraints commonly encountered in existing, developed areas can limit the type of stormwater retrofits that are possible for a site and their overall effectiveness. Retrofit of an existing stormwater management facility according to the design standards contained in Chapter Eleven of this Manual may not be possible due to site-specific factors such as the location of existing utilities, buildings, wetlands, maintenance access, and adjacent land uses. **Table 10-1** lists site-specific factors to consider in determining the appropriateness of stormwater retrofits for a particular site.

Retrofitted facilities may not be as effective in reducing pollutant loads as newly designed and installed facilities. However, in most cases, some improvements in stormwater quantity and quality control are possible, especially if a new use is planned for an existing development or an existing storm drainage system is upgraded or expanded. Incorporation of a number of small-scale LID management practices or a treatment train approach may be necessary to achieve the desired level of effectiveness. It should also be recognized that stormwater quantity frequently creates the most severe impacts to receiving waters and wetlands as a result of channel erosion (Claytor, Center for Watershed Protection, 2000). Therefore, stormwater quantity control functions that existing stormwater management facilities provide should not be significantly compromised in exchange for pollutant removal effectiveness.

10.4 Stormwater Retrofit Options

Stormwater retrofit options include many of the same source control and stormwater treatment practices for new developments that are described in other chapters of this Manual. Common stormwater retrofit applications for existing development and redevelopment projects include:

- *Stormwater drainage system retrofits*
- *Stormwater management facility retrofits*

Table 10-1 Site Considerations for Determining the Appropriateness of Stormwater Retrofits

Factor	Consideration
Retrofit Purpose	What are the primary and secondary (if any) purposes of the retrofit project? Are the retrofits designed primarily for stormwater quantity control, quality control, or a combination of both?
Construction/Maintenance Access	Does the site have adequate construction and maintenance access and sufficient construction staging area? Are maintenance responsibilities for the retrofits clearly defined?
Subsurface Conditions	Are the subsurface conditions at the site (soil permeability and depth to groundwater/bedrock) consistent with the proposed retrofit regarding subsurface infiltration capacity and constructability?
Utilities	Do the locations of existing utilities present conflicts with the proposed retrofits or require relocation or design modifications?
Conflicting Land Uses	Are the retrofits compatible with adjacent land uses of nearby properties?
Wetlands, Sensitive Water Bodies, and Vegetation	How do the retrofits affect adjacent or downgradient wetlands, sensitive receiving waters, and vegetation? Do the retrofits minimize or mitigate impacts where possible?
Complementary Restoration Projects	Are there opportunities to combine stormwater retrofits with complementary projects such as stream stabilization, habitat restoration, or wetland restoration/mitigation?
Permits and Approvals	Which local, state, and federal regulatory agencies have jurisdiction over the proposed retrofit project, and can regulatory approvals be obtained for the retrofits?
Public Safety	Does the retrofit increase the risk to public health and safety?
Cost	What are the capital and long-term maintenance costs associated with the stormwater retrofits? Are the retrofits cost-effective in terms of anticipated benefits?

Source: Adapted from Claytor, Center for Watershed Protection, 2000.

- *New stormwater controls at storm drain outfalls*
- *New stormwater controls for road culverts and rights-of-way*
- *In-stream practices in existing drainage channels*
- *Parking lot stormwater retrofits*
- *Wetland creation and restoration*

Examples of these stormwater retrofits are described in the following sections.

10.4.1 Stormwater Drainage Systems

Existing drainage systems can be modified to improve water quality mitigation and sediment removal functions. These retrofits alone typically provide limited benefits, but are most successful when used in conjunction with other source controls and stormwater treatment practices. Due to their very nature as an integral part of the stormwater collection and conveyance system and inherent solids trapping function, these retrofits typically have high maintenance requirements. Common examples of stormwater drainage system retrofits include:

Deep Sump Catch Basins with Hoods: Older catch basins without sumps can be replaced with catch basins having four to six-foot deep sumps. Sumps provide storage volume for coarse sediments, provided that accumulated sediment is removed on a regular basis. Hooded outlets, which are covers over the catch basin outlets that extend below the standing water, can also be used to trap litter and other floatable materials. A recent study conducted in New York City demonstrated that catch basins equipped with hoods increase the capture of floatables by 70 to 80 percent over catch basins without hoods and greatly extend the cleaning interval without degraded capture performance (Pitt, 1999 in NRDC, 1999).

Catch Basin Inserts and Storm Drain Structures: As discussed in Chapter Six, a number of manufactured devices have been developed that can be inserted into storm drains or catch basins to capture sediment and other pollutants directly beneath the grate. These products typically utilize filter media or vortex action for removal of solids from incoming stormwater runoff. These devices are ideally suited for developed sites since they fit inside of or replace existing catch basins, or are installed beneath existing parking lots with minimal or no additional space requirements.

10.4.2 Stormwater Management Facilities

Existing stormwater management facilities originally designed for flood control can be modified or reconfigured for water quality mitigation purposes or increased hydrologic benefit. Older detention facilities offer the greatest opportunity for this type of retrofit. Traditional dry detention basins can be modified to become extended detention basins, wet ponds, or stormwater wetlands for enhanced pollutant removal. This is one of the most common and easily implemented retrofits since it typically requires little or no additional land area, utilizes an existing facility for which there is already some resident acceptance of stormwater management, and involves minimal impacts to environmental resources (Claytor, Center for Watershed Protection, 2000).

Specific modifications to existing detention basins for improved water quality mitigation are summarized in **Table 10-2.** Stormwater detention basin retrofits should include an evaluation of the hydraulic characteristics and storage capacity of the basin to determine whether available storage exists for additional water quality treatment. A typical retrofit of an existing detention basin is shown in **Figure 10-1**.

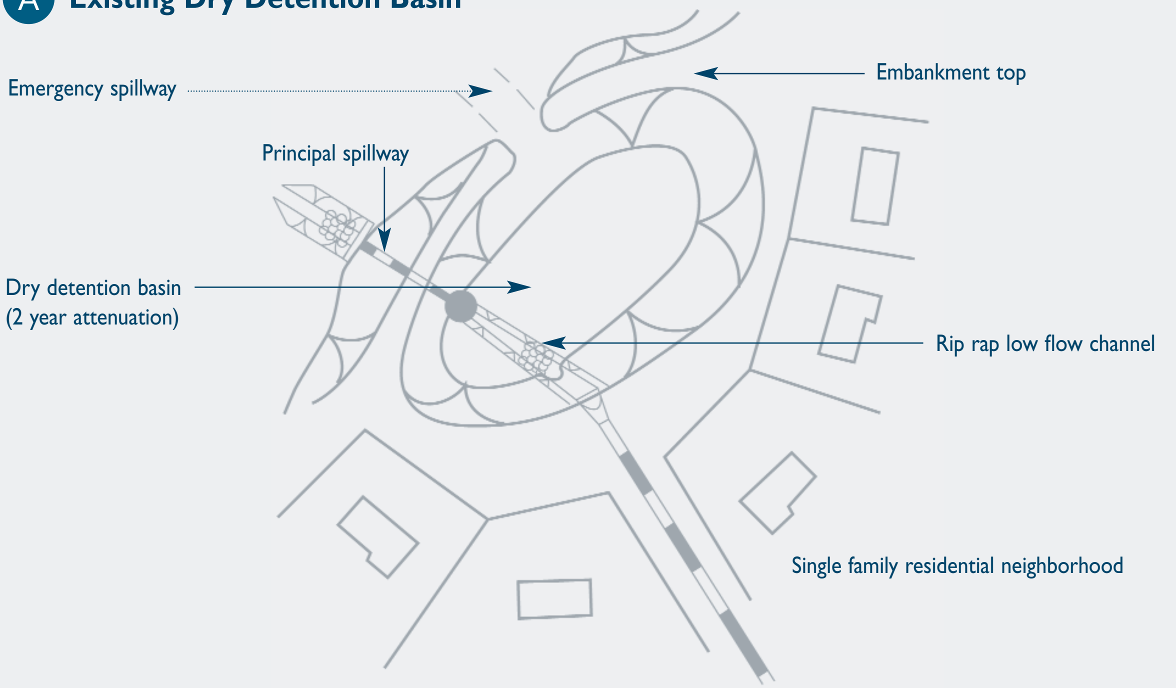
Table 10-2
Detention Basin Retrofits for Improved Water Quality Mitigation

Excavate the basin bottom to create more permanent pool storage	Eliminate low-flow bypasses
Raise the basin embankment to obtain additional storage for extended detention	Incorporate stilling basins at inlets and outlets and sediment forebays at basin inlets
Modify the outfall structure to create a two-stage release to better control small storms while not significantly compromising flood control detention for large storms	Regrade the basin bottom to create a wetland area near the basin outlet or revegetate parts of the basin bottom with wetland vegetation to enhance pollutant removal, reduce mowing, and improve aesthetics
Increase the flow path from inflow to outflow and eliminate short-circuiting by using baffles, earthen berms, or micro-pond topography to increase residence time of water in the pond and improve settling of solids	Create a wetland shelf along the perimeter of a wet basin to improve shoreline stabilization, enhance pollutant filtering, and enhance aesthetic and habitat functions
Replace paved low-flow channels with meandering vegetated swales	Create a low maintenance "no-mow" wildflower ecosystem in the drier portions of the basin
Provide a high flow bypass to avoid resuspension of captured sediment/pollutants during high flows	

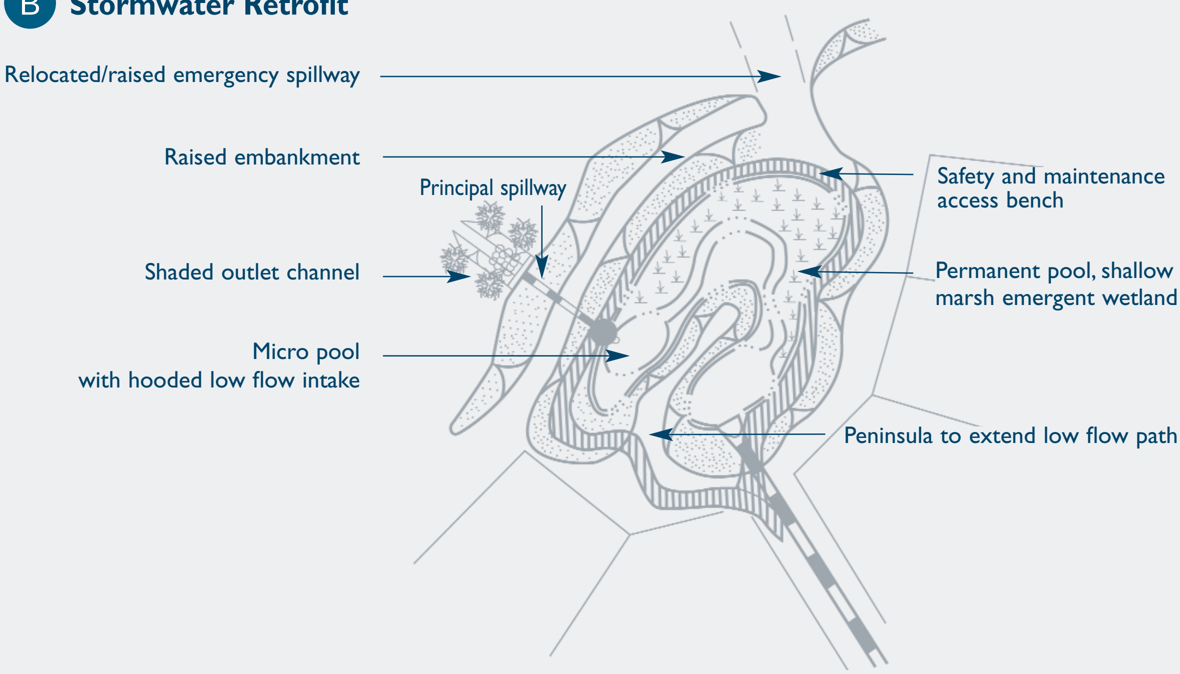
Source: Adapted from Claytor, Center for Watershed Protection, 2000; Pennsylvania Association of Conservation Districts et al., 1998; and NJDEP, 2000.

Figure 10-1 Stormwater Retrofit of an Existing Dry Detention Basin

A Existing Dry Detention Basin

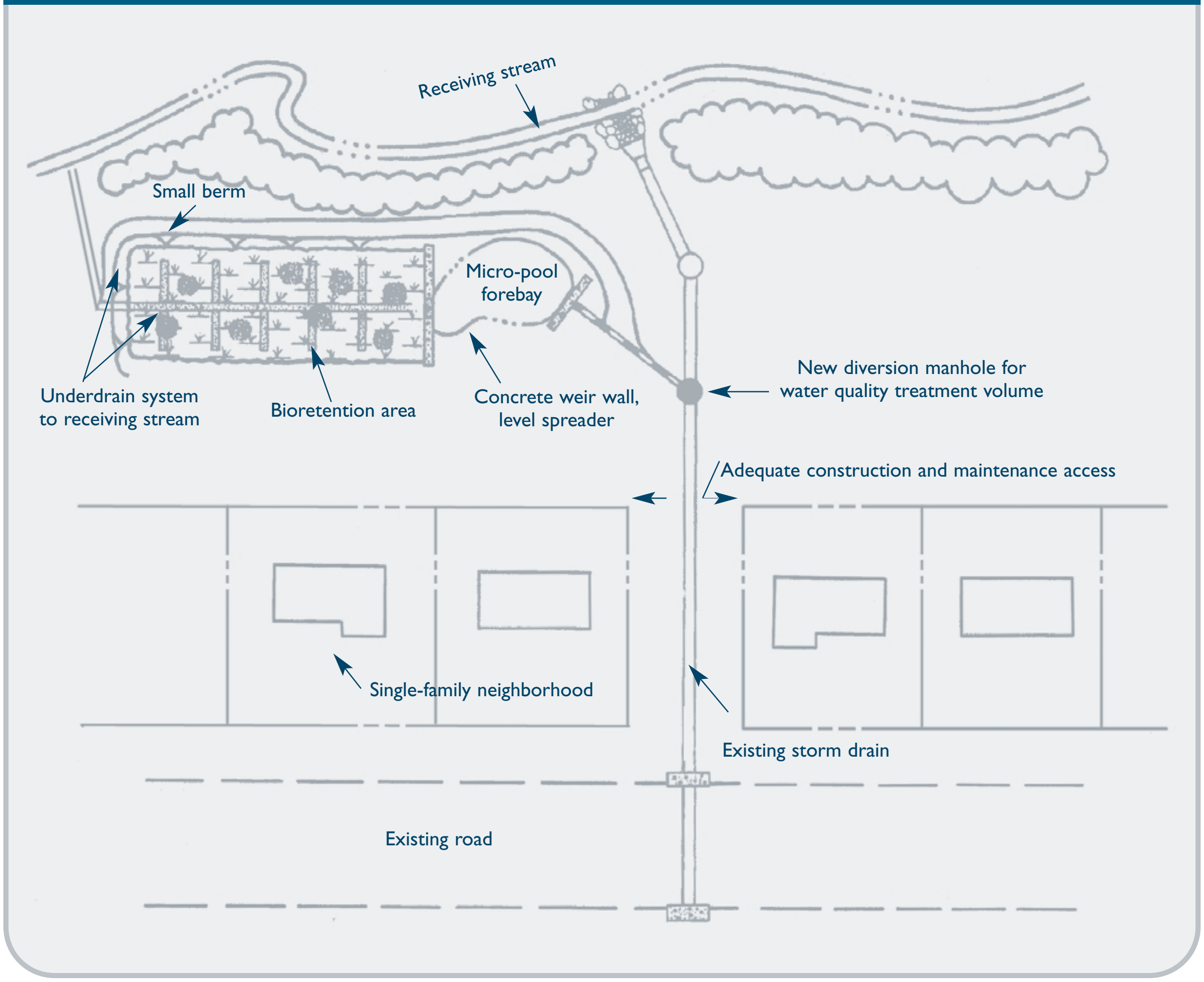


B Stormwater Retrofit



Source: Claytor, Center for Watershed Protection, 2000.

Figure 10-2 Typical Stormwater Retrofit at Existing Storm Drain Outfall



Source: Claytor, Center for Watershed Protection, 2000.

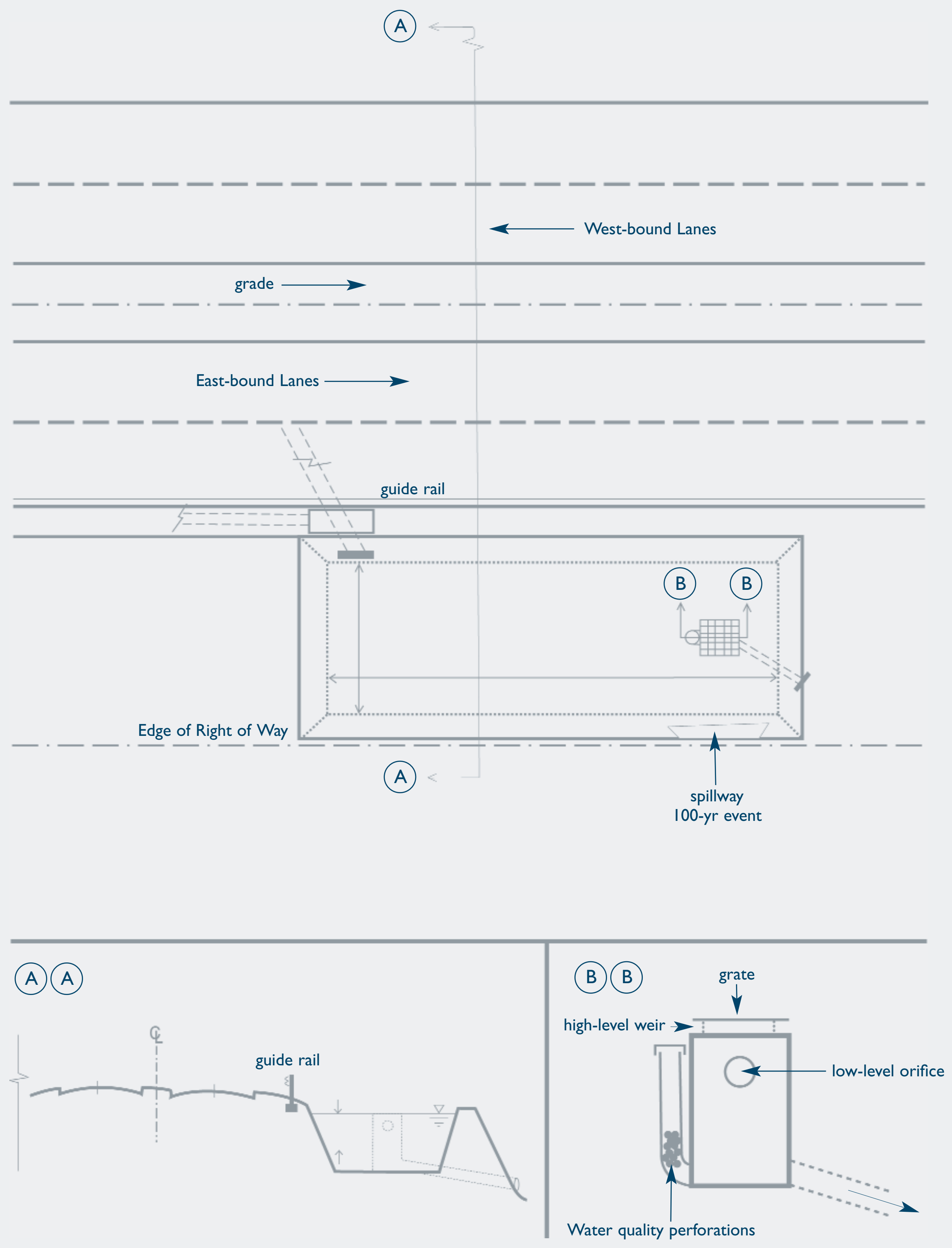
10.4.3 Storm Drain Outfalls

New stormwater treatment practices can be constructed at the outfalls of existing drainage systems. The new stormwater treatment practices are commonly designed as off-line devices to treat the water quality volume and bypass larger storms. Water quality swales, bioretention, sand filters, constructed wetlands, and wet ponds are commonly used for this type of retrofit, although most stormwater treatment practices can be used for this type of retrofit given enough space for construction and maintenance. **Figure 10-2** shows a schematic of an existing outfall retrofitted with an off-line bioretention area. Manufactured, underground treatment devices such as those described in Chapter Six are also commonly installed as off-line retrofits at or upgradient of stormwater outfalls. Velocity dissipation devices such as plunge pools and level spreaders can also be incorporated into the retrofit design.

10.4.4 Highway Rights-of-Way

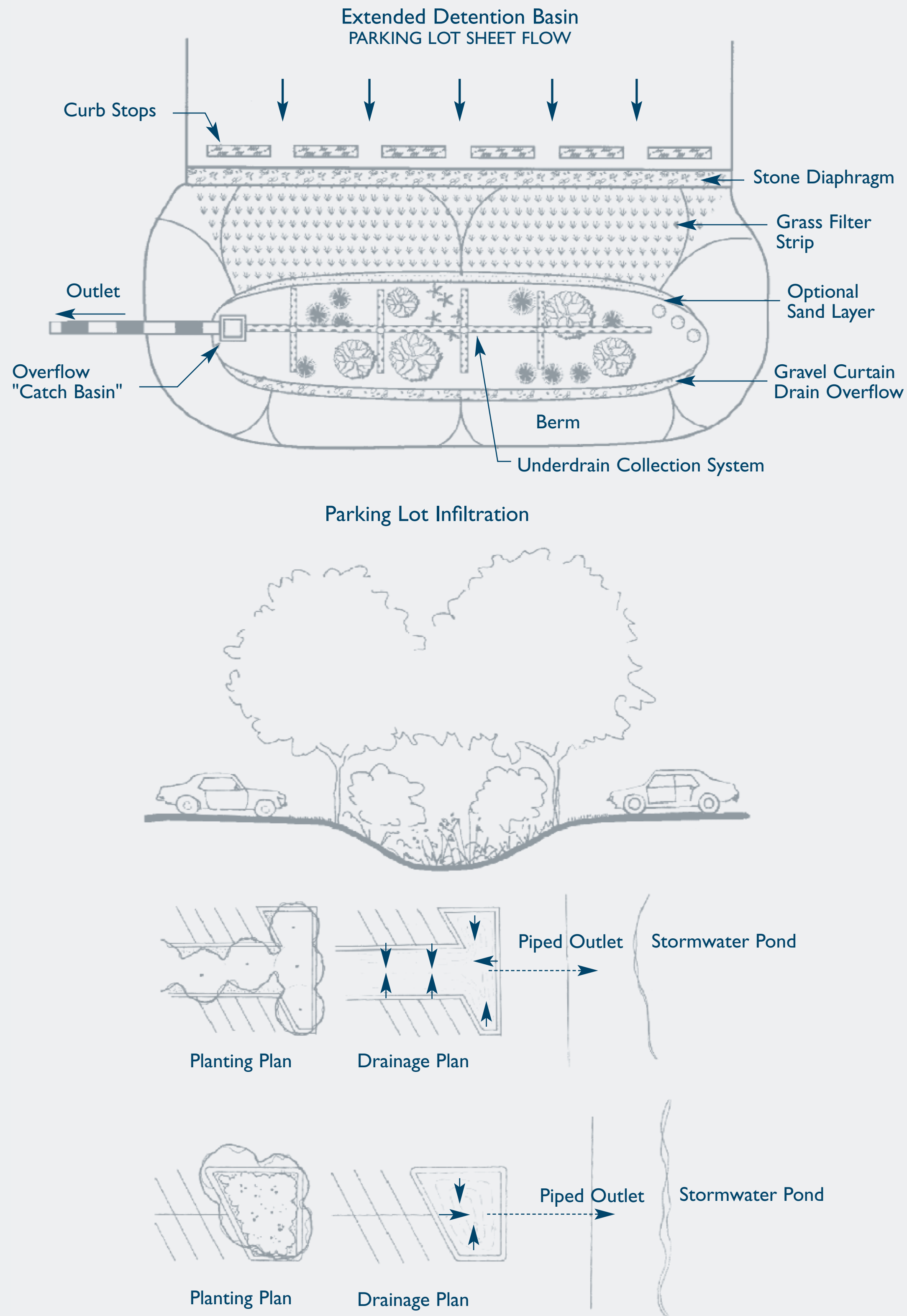
Open spaces associated with highway rights-of-way such as medians, shoulders, and cloverleaf areas also present opportunities to incorporate new stormwater treatment practices. Common treatment practices used in these types of retrofits include vegetated swales, bioretention, constructed wetlands, and extended detention ponds. Traffic, safety, and maintenance access are important considerations for determining appropriate locations for highway right-of-way retrofits. **Figure 10-3** shows a schematic of an extended detention basin incorporated into an existing highway right-of-way.

Figure 10-3 Stormwater Retrofit in Highway Right-of-Way



Source: Adapted from Federal Highway Administration, 1996.

Figure 10-4 Parking Lot Stormwater Retrofit Schematics



Source: Metropolitan Council, 2001 (Adapted from VBWD, 2000) and NYDEC, 2001

10.4.5 Parking Lots

Parking lots can be ideal candidates for a wide range of stormwater retrofits. Potentially applicable retrofits include site planning techniques and small-scale management measures to reduce impervious coverage and promote increased infiltration (see Chapter Four), as well as a variety of larger, end-of-pipe treatment practices. Redevelopment of older commercial properties, which were often designed with oversized parking lots and almost 100 percent impervious coverage, is one of the most common and environmentally beneficial opportunities for parking lot stormwater retrofits.

Alternative site design and LID management practices are well suited to existing developed areas because most of these practices use a small amount of land and are easily integrated into existing parking areas. Examples of these parking lot stormwater retrofits include:

Incorporating Bioretention Into Parking Lot Islands and Landscaping: Parking lot islands, landscaped areas, and tree planter boxes can be converted into functional bioretention areas and rain gardens to reduce and treat stormwater runoff.

Removing Curbing and Adding Slotted Curb Stops: Curbs along the edges of parking lots can sometimes be removed or slotted to re-route runoff to vegetated areas, buffer strips, or bioretention facilities. The capacity of existing swales may need to be evaluated and expanded as part of this retrofit option.

Infiltrating Clean Roof Runoff From Buildings: In some instances, building roof drains connected to the stormwater drainage system can be disconnected and re-directed to vegetated areas, buffer strips, bioretention facilities, or infiltration structures (dry wells or infiltration trenches).

Incorporating New Treatment Practices at the Edges of Parking Lots: New stormwater treatment practices such as bioretention, sand filters, and constructed wetlands can often be incorporated at the edges of large parking lots.

Use of Permeable Paving Materials: Existing impermeable pavement in overflow parking or other low-traffic areas can sometimes be replaced with alternative, permeable materials such as modular concrete paving blocks, modular concrete or plastic lattice, or cast-in-place concrete grids. Site-specific factors including traffic volumes, soil permeability, maintenance, sediment loads, and land use must be carefully considered for the successful application of permeable paving materials for new development or retrofit applications.

Figure 10-4 depicts some of the parking lot stormwater retrofits described above.

10.4.6 In-stream Practices in Drainage Channels

Existing (man-made) channelized streams and drainage conveyances such as grass channels can be modified to reduce flow velocities and enhance pollutant removal. Weir walls or riprap check dams placed across a channel create opportunities for ponding, infiltration, and establishment of wetland vegetation upstream of the retrofit (Claytor, Center for Watershed Protection, 2000). In-stream retrofit practices include stream bank stabilization of eroded areas and placement of habitat improvement structures (i.e., flow deflectors, boulders, pools/riffles, and low-flow channels) in impacted natural streams and along stream banks. In-stream retrofits may require evaluation of potential flooding and floodplain impacts resulting from altered channel conveyance, as well as local, state, or federal approval for work in wetlands and watercourses. More comprehensive urban stream and stream corridor restoration practices are beyond the scope of this Manual. Additional sources of information on stream restoration practices are included at the end of this chapter.

10.4.7 Wetland Creation and Restoration

Wetland creation or restoration can partially substitute for lost ecological functions of a destroyed or degraded wetland system in developed areas. Creation or restoration of freshwater or tidal wetlands can improve the pollutant removal, longevity, adaptability, and habitat functions of wetland systems (DEP, 1995). Techniques to improve pollutant removal in created or restored wetlands include:

- *Increasing wetland volume to increase residence time*
- *Increasing the surface area to volume ratio of the wetland*
- *Increasing the flow path through the wetland*
- *Providing energy dissipation and primary sedimentation either prior to the wetland or in a sediment forebay at the wetland inflow locations*
- *Integrating with other treatment practices such as extended detention*

(Schueler et al., 1992) When wetlands are altered through clearing of vegetation, impoundment of water, or dredging, the microhabitats used by many wildlife species are changed or lost. This may result in unsuitable breeding habitat for many amphibians, including vernal pool species. Similarly, created wetlands usually lack the structural diversity, microhabitats, and hydrology to support vernal pool breeding amphibians (Calhoun and Klemens, 2002). Altered and created wetlands often support highly adaptable, widespread, "weedy" species (e.g., bullfrogs or green frogs) that prey upon, or successfully out-compete, vernal pool-breeding amphibians, which reduces or locally eliminates populations of these habitat specialists. Created wetlands that do not have the appropriate habitat often attract breeding amphibians, which serve as "decoy" pools and trap breeding amphibians. Therefore, these wetland creation and restoration techniques should only be implemented with careful consideration of the effects to wetland function and hydrology and in conjunction with applicable local, state, and federal wetland and watercourses regulatory agencies.

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