
Operation,
Maintenance,
& Management
of
Stormwater
Management
Systems

Operation, Maintenance, and Management of Stormwater Management Systems

Produced by the:

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Produced by the Watershed Management Institute, Inc.

Principal Authors:	**Eric H. Livingston** **Earl Shaver** **Joseph J. Skupien, P. E.**
Contributing Author:	**Richard R. Horner, Ph. D.**

Watershed Management Institute
P.O. Box 14
Ingleside, Maryland 21644
Phone: 410/758-2731
Fax: 410/758-0386

Watershed Management Institute
410 White Oak Drive
Crawfordville, Florida 32327
Phone: 850/926-5310
Fax: 850/926-1534

Printed on recycled paper

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Chapter 1
Introduction

1. WHY IS STORMWATER SYSTEM OPERATION, MAINTENANCE, AND MANAGEMENT IMPORTANT?

Over the last two decades, stormwater management systems have evolved considerably from their traditional roles as conveyance devices that are only intended to transport stormwater runoff safely and efficiently from one location to another. Such conveyance systems have included bridges, culverts, ditches, and the ubiquitous piped storm drain (sewer). However, in response to growing concerns over nonpoint source (NPS) pollution, flooding, and erosion, a new type of stormwater system has been created. This type not only conveys runoff, but also manages it by deliberately modifying its flow rate, volume, and/or water quality. These stormwater management systems rely upon practices such as infiltration or retention areas, extended dry or wet detention, sand filters, vegetated swales, and constructed wetlands.

Whether designed for conveyance or management, all stormwater systems require proper design, construction, and maintenance to perform successfully. However, due to their more demanding duties and objectives, today's multipurpose stormwater practices have proven themselves to be inherently more complex than their more traditional conveyance counterparts. Accordingly, they require a much greater level of effort by those who design, construct, maintain, and operate them.

This is particularly true for stormwater management system maintenance and management. Maintenance has always been recognized as vital to the proper and prolonged performance of all stormwater systems. However, ***thorough and consistent maintenance is particularly crucial to the successful performance of stormwater treatment practices***, an importance that carries over to the entire stormwater management program they support. Reasons for this increased importance include:

- As noted above, stormwater management systems are inherently more complex than traditional runoff conveyances. Not only in their function or operation, but also in the number and types of materials used to construct them. This may even include natural materials such as aquatic vegetation and microorganisms. This increased complexity and variety demands a greater level of maintenance and management to assure safe and effective operation.

- Unlike drainage systems, many stormwater practices achieve their management goals through impoundment or storage of runoff instead of conveyance. This is accomplished through the use of dams, berms, tanks, or chambers. To successfully impound water, either temporarily (for example, in a dry detention or infiltration basin) or permanently (in a wet detention pond or constructed wetland), requires a greater degree of structural strength. Safely impounding stormwater requires more safeguards to avoid the possibly catastrophic downstream damage caused by structural failure and sudden release of the impounded water. These increased levels of strength and safety, which must be provided continually throughout the life of the stormwater management facility, demand a similarly higher level of maintenance.

- Stormwater conveyances and flood control systems typically are designed to transport or impound the runoff from a relatively rare storm event, with a recurrence interval of 25 to 100-years. As such, they may experience maximum design conditions only a few times during their lifetime. However, ***stormwater management systems***, particularly those ***intended to treat runoff*** and reduce pollutants, typically are designed to capture smaller, more frequent rainfall/runoff events (e.g., half inch storm; 2-yr, 1-hr storm). Therefore, they **may experience maximum design conditions several times each year**. This more frequent and repetitive operation at their design limit creates more stress, which again demands greater attention and commitment to proper maintenance and management.

- ***Failure to perform adequate maintenance of stormwater management systems*** not only leads to reductions in expected or desired performance levels, but ***may even create conditions that are worse than if the facility had not been constructed*** at all. For example, a neglected dam may fail and release impounded water onto downstream properties, an eroding swale may be the source of excessive sediment, or a poorly managed constructed wetland may create harmful levels of nutrients or temperature.

Stormwater management has become an important part of our efforts to achieve clean water and a safe environment. However, as seen above, neglect of stormwater management systems not only poses a threat to those living downstream, but it can also undermine the entire stormwater management program that led to their creation. The importance of regular inspection and thorough stormwater system maintenance can not be understated. In fact, ***stormwater systems should not even be constructed if the stormwater program is not willing to make the necessary commitments to assure that the systems are properly maintained, managed, and operated.***

The objective of this handbook is to help assure that necessary maintenance and management of stormwater systems is performed. The handbook is aimed at a diverse audience - all of those individuals and groups which have been shown by both experience and research to play an important role in a successful stormwater management system maintenance program. This includes persons involved in developing and implementing stormwater management programs, stormwater system designers and builders, land developers and their consultants, stormwater system plan reviewers and inspectors, stormwater system owners and operators, public officials, and all citizens.

2. CHAPTER CONTENTS

The handbook is divided into eight additional chapters, each addressing an important aspect of stormwater system operation and maintenance:

Chapter 2 - Stormwater Management Practices ***presents an overview of several different types of commonly used stormwater management practices***. These include infiltration or retention systems, wet and dry detention systems, constructed wetlands, vegetated swales, and filtration systems such as sand filters and biofiltration systems. For each type of practice, information is presented on its basic runoff quantity and quality control mechanisms, pollutant removal potentials, site and operating limitations, and operation and maintenance obligations. This presentation of ***basic information is intended to improve the understanding of the needs and limitations of each practice by those who design, regulate, construct, own, operate, or maintain them***. All of these individuals play a vital role in assuring proper maintenance and operation of the practice.

Chapter 3 - Planning and Design Considerations ***is addressed directly to stormwater management system planners and designers. Information is presented which demonstrates how proper planning and design can help to both minimize and facilitate system maintenance***. The maintenance problems that can result from inadequate or inattentive planning or design are also highlighted. Additionally, planning and design guidelines to help achieve minimum maintenance goals are presented for each type of stormwater management practice described in Chapter 2. This information ***stresses the importance of simplicity, accessibility, and durability in designing stormwater management systems***.

Chapter 4 - Programmatic and Regulatory Aspects ***highlights the key role that program implementers play in achieving proper levels of stormwater management system maintenance and how their ignorance or indifference can lead to maintenance neglect and facility failure***. Proper planning, design, and construction all contribute to a successful maintenance program. However, the key to success is ensuring that each of these activities gets done, a role for which program implementation staff are uniquely suited. To achieve this goal, ***implementation staff must become as involved in the maintenance of stormwater management systems as they are with the planning, design, and construction***. Maintenance of stormwater systems can not simply be left for others to resolve. ***Guidance for establishing the proper institutional framework and standards is provided***, including essential program aspects such as mandatory operation and maintenance plans, designating responsible entities, operating permits, enforcement options, and maintenance default contingency plans.

Chapter 5 - Owner, Operator, and User Considerations ***provides each of these individuals and groups with important information regarding how their system works, why it is needed, and what maintenance it will require***. It also explains in clear terms why it is in their best interest to provide thorough and consistent levels of system maintenance and how maintenance neglect on their part can lead to serious environmental, safety, and legal problems. The Chapter also provides suggestions for establishing a successful maintenance program and will discuss the environmental, financial, aesthetic, and civic rewards for doing so.

Chapter 6 - Construction Inspection ***highlights a vital but often overlooked aspect of successful stormwater management system maintenance***. It is the inspectors who must complete the job started by the administrators, planners, and designers, and who must provide the owners, operators, and maintainers with a sound, durable facility that is worthy of their maintenance investment. ***The Chapter assists construction inspectors*** **by** ***providing detailed checklists of important inspection items during each stage of construction***. It also emphasizes the importance of system construction scheduling, phasing, and coordination with other site activities and promotes close coordination and communication between inspectors, contractors, owners, designers, and reviewers. Finally, recommendations for establishing training and certification programs for inspectors are also provided, including a model program curriculum.

Chapter 7 - Post-Construction Inspection and Maintenance ***presents pertinent information to the final members of the overall maintenance team - those responsible for inspecting, scheduling, and performing the actual maintenance and management of stormwater management systems***. This Chapter seeks to address a deficiency in many state and local stormwater management programs. It provides detailed information to both inspectors and owner/operators and emphasizes the importance of both groups to the success of the overall stormwater management program. ***Inspectors are provided with checklists detailing a comprehensive system inspection program***, including recommended inspection frequencies and a breakdown of inspection practices by system component. ***Owner/operators are presented with descriptions of typical maintenance tasks, including recommended equipment, techniques, materials, and frequencies***. Finally, information on developing a training and certification program for those who perform system maintenance is also presented.

Chapter 8 - Maintenance Costs and Financing discusses an aspect of stormwater management system maintenance that is of interest to everyone from administrators to owners, and which is vital to the success of any stormwater management program. ***Summaries of expected or typical costs for various maintenance tasks, both regular and episodic, are presented***. Estimated costs of materials and equipment also are provided. In addition, various means of financing these costs are discussed, with examples of various institutional programs highlighted.

Chapter 9 - Disposal of Sediments ***presents information on a new issue of concern*** that emphasizes both the complex nature of stormwater management systems and the need for a comprehensive maintenance program. Sedimentation is one of the primary mechanisms for pollutant removal in many stormwater management systems. As a result, the sediment collected in the facility may contain heavy metals, hydrocarbons, greases, nutrients, and other pollutants depending upon the character and use of the land draining to the system. ***Depending upon their concentrations and quantities, these pollutants may pose disposal problems for facility owners, operators, and maintainers***. General recommendations for analyzing and properly disposing of these sediments are presented along with a discussion of potential regulatory constraints.

As can be seen from the above review, stormwater management system maintenance is a broad and complex topic. It is hoped that this handbook attracts an equally broad and diverse group of readers. ***To assist readers find the information they seek quickly, each chapter in the handbook begins with a brief summary of its contents, including the goals of the Chapter and a list of its intended readers***. This should allow the reader to quickly assess the contents of each Chapter and determine its applicability to his or her interests or needs. To further guide the reader, major topics within each chapter are presented under their own descriptive headings.

3. HANDBOOK BMP TERMINOLOGY

The field of stormwater management has grown considerably in the past two decades. This growth has produced, among many accomplishments, a long and sometimes conflicting list of names for various stormwater management practices. Unfortunately, these names can vary by state or region. This can confuse or mislead the experienced practitioner, not to mention the new reader. Therefore, in order to minimize such confusion and maximize the handbook's effectiveness, the following general definitions have been adopted for use in the handbook:

3.1. Detention Practice:

A stormwater management practice which temporarily impounds runoff and discharges it through an outlet structure. Any additional outflow through infiltration or evaporation is negligible and, therefore, not ordinarily considered in the facility's design. Detention practices may be either wet or dry. They often are divided into three categories:

A. Dry detention practices which detain runoff for a relatively short time (1 to 24 hours) and release it at a controlled rate until the system is once again dry.

B. Extended dry detention practices which detain runoff for a longer time (24 to 48 hours), thereby increasing sedimentation and pollutant removal before the runoff is released at a controlled rate and the system is once again dry.

Extended Dry Detention System

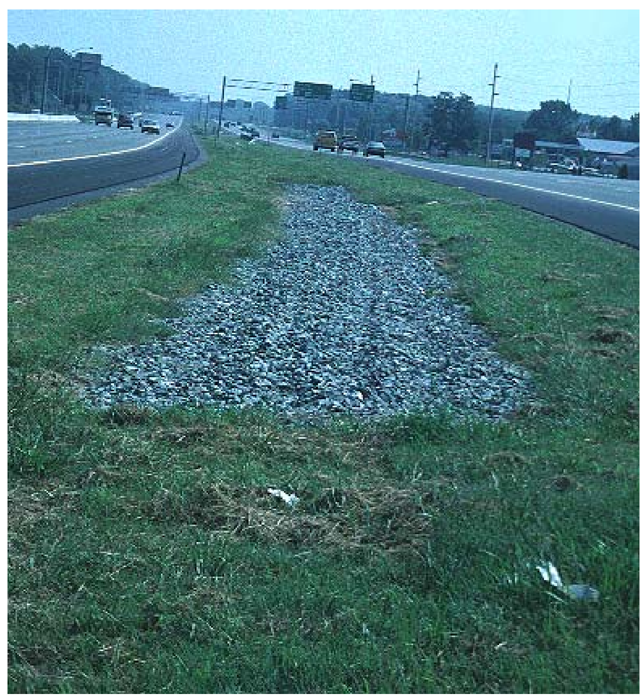
C. Wet detention practices, or wet ponds, which have a permanent pool of water, detain and release runoff over five days or even longer, and allow sedimentation, flocculation, and chemical and biological processes to occur, reducing stormwater pollutants. During and immediately after storms, runoff is temporarily stored above the permanent water pool.

Wet Detention System (Pond)

3.2. Infiltration (Retention) Practices:

A stormwater management practice which temporarily impounds a specified amount of runoff (treatment volume), retains it on-site, and discharges it through percolation into the underlying soil and by evapotranspiration. Online practices typically will have outlet structures to safely convey the flood control volume, and emergency overflows from extreme storm events. Infiltration practices are expected to be dry during non-rainfall periods. The retention practice tool box includes infiltration basins and trenches, swales, pervious pavements, dry wells, and seepage pits.

Infiltration Trench



3.3 Filtration Practices:

A stormwater management system which filters the runoff through a medium to remove pollutants, especially particulate pollutants.

Sand Filtration Facility

Filter systems usually are used in combination with detention systems. Filter media include mixtures of sand, peat, and compost. Filters can be either confined (in boxes, bags, etc.) or unconfined. They can be designed as sidebank or vertical systems, meaning that the water flow is sideways or downward, respectively.

3.4 Biofiltration Practices:

A stormwater management system which incorporates vegetative filtration, allowing runoff to slowly pass through the vegetation to reduce pollutants. In addition to vegetative filtering, these systems may also promote the infiltration of runoff, depending on soil conditions. The organic nature of the soils and supporting vegetation helps reduce the potential for ground water contamination. Biofiltration practices include swales, buffer strips, and bioretention areas.

Swale with a swale block.

Chapter 2
Stormwater Management Practices

1. OVERVIEW

State and local governments have implemented a wide variety of programs to address the stormwater problems resulting from changes to land use. Traditionally, these programs have focused on the prevention or minimization of flooding to protect the homes, buildings, property and lives of their citizens. "Drainage" ordinances and programs have been established in most communities. Today, however, existing ***stormwater programs must evolve and become more comprehensive to address stormwater management objectives which extend beyond the traditional drainage focus. Expanded program objectives now include: erosion and sediment control during construction, water quality protection, stormwater reuse, and open space and recreation.***

The tools or management practices that are used to prevent and mitigate these stormwater impacts also need to evolve. ***This chapter will review the stormwater management practices that are most commonly used for stormwater treatment. For each practice the pollutant removal mechanisms, expected performance, limitations on use, and operation, maintenance and management needs will be discussed and summarized.*** Additionally, for each practice, specific operation, maintenance, and management recommendations will be made.

1.1. Intended Readers

This chapter is intended for all readers of this publication. It's information will be useful to:

- **Persons involved in developing and implementing stormwater management programs.**
- **Stormwater system designers and builders.**
- **Land developers and their consultants.**
- **Stormwater system plan reviewers and inspectors.**
- **Stormwater system owners or operators.**
- **Public officials and citizens.**

2. STORMWATER MANAGEMENT PROGRAM CONSIDERATIONS

Before discussing stormwater practices, stormwater management program considerations will be briefly reviewed. ***Successful stormwater management requires more than simply the use of runoff control techniques. It also requires a strong institutional foundation.*** A key component of this foundation is establishing effective mechanisms to assure that stormwater systems not only are designed and constructed correctly, but that they also are inspected, maintained and operated properly.

2.1 Stormwater Program Components

This section briefly discusses the many components of a successful stormwater management program. No single framework for a stormwater management program can be recommended. Flexibility is needed to establish or refine programs, based on an area's existing legal authorities and institutional framework.

Experience has shown that no single entity can do everything. ***Program implementation typically will be shared by a partnership involving all appropriate levels of government, together with the public sector and all citizens. Cooperation and coordination among all of the partners involved in program implementation are cornerstones of successful programs.*** It is especially important that the roles of each partner involved in program implementation be clearly stated. This will help to avoid duplication and distribute program activities to the entity most suited for the role. This is especially true for assuring the long term performance of stormwater management practices.

Experience also has shown that successful stormwater management programs share several common building blocks (WMI, 1997). These involve the program's institutional framework, its technical foundations, and the many activities that are undertaken by the stormwater program (Figure 2-1).

2.2. Stormwater Program Evolution to Address Existing Development

Stormwater quality management programs typically must be phased in. They usually must be integrated with existing "drainage" programs to provide coordinated management of stormwater quantity and quality. ***Initial program efforts are aimed at preventing and mitigating stormwater problems from new development, both during and after construction***. Generally, these programs rely upon on-site planning and BMP implementation. Once all aspects, including inspections and operation/maintenance, of this new development program are running smoothly, the program can be expanded to correct stormwater problems caused by existing development and land uses (retrofitting). Section 2.3 discusses important components of programs aimed at stormwater from new development.

Establishing a program to retrofit existing stormwater systems, however, presents many technical, institutional, financial, and cultural dilemmas. In many instances, the unavailability or high cost of land in urban areas makes the use of conventional BMPs infeasible. State laws and institutional arrangements promote piecemeal, crisis-solving approaches aimed at managing stormwater within political boundaries — yet stormwater follows watershed boundaries. Retrofitting often is prohibitively expensive. With many local governments already short of funds, the need for innovative, dedicated stormwater funding sources, such as stormwater utility fees, cannot be overemphasized. Finally, cultural change is needed to get citizens and businesses to embrace nonstructural BMPs and to support the stormwater program.

Solving existing stormwater problems will require comprehensive, coordinated, creative approaches and technology. Essential elements of a comprehensive, long-term effort to reduce pollutant loadings from existing land uses and older stormwater systems include:

<u>A. Watershed Management</u>

A watershed approach which integrates land use planning with the development of stormwater infrastructure is essential. After all, ***it is the intensification of land use and the increase in impervious surfaces within a watershed that creates the stormwater and water resources management problems***. Consequently, a “watershed management team” effort is necessary which involves state, regional and local

PROGRAM ACTIVITIES

Inspections
- Erosion/sediment controls
- Stormwater system construction
- Stormwater system operation

Stormwater system operation/maintenance
- Public facilities
- Private facilities
- Adopt a pond program

Plan review and approval
- Site plans
- Erosion control plans
- Stormwater plans

Education programs
- School curriculum
- General public
- Elected officials
- Designers
- Developers
- Builders
- Inspectors
- Practitioners

Structural BMPs
- Design criteria
- Research/performance
- Proper construction
- Proper operation
- Maintenance

Administration
- Lead agency?
- Separate agency?

Staffing
- Engineers
- Inspectors
- Planners
- Scientists
- Maintenance
- Clerical

Compliance/enforcement
- Stop work orders
- Fines
- Civil or criminal

Performance standards
- Peak discharge rate
- Volume
- Treatment

Program evaluation
- Citizen surveys
- Bldg. community surveys
- BMP monitoring
- Water body monitoring

Stormwater retrofitting
- Watershed goal
- Targeting/prioritization
- Capital improvements
- Regional BMPs

Nonstructural BMPs
- Site planning
- Source controls
- Street sweeping

Local land use plan

Stormwater master planning

Watershed planning

Integration with other federal, state and local programs

Adopt program laws/regulations

Adopt stormwater utility ordinance/fees

Legal Authority | **Funding** | **Staffing** | **Public Support** | **Govt. Roles Responsibilities**

Cumulative Impacts | **Comprehensive** | **Continuity** | **Cooperation** | **Communication** | **Coordination** | **Creativity** | **Common Sense** | **Commitment**

Figure 2 -1. Cornerstones (the Big Cs), Building Blocks, and Activities of a Stormwater Management Program

governments, together with the private sector and all citizens within a watershed.

B. Treatment Requirements for Older Systems (Retrofitting)

Numerous problems inherent to a highly urbanized area make it nearly impossible to apply the same stormwater design and performance standards that are applied to new developments. Instead, a "watershed loading" concept should be considered. This "big picture" approach considers the beneficial uses of the receiving waters, assesses the loadings from all pollution sources, and establishes the maximum loadings of pollutants that can be assimilated by those waters. A key element is setting a "stormwater pollutant load reduction goal" for existing untreated stormwater discharges. An ecologically based goal should be established, such as increasing the area of sea grasses or restoring habitat for desired aquatic species. It is important that the ecologically-based goal is understood by the public and determined with broad community participation.

Success in meeting the load reduction goal will depend not only on the treatment benefits from retrofitting projects, but also by assuring that the on-site systems serving new development are constructed, operated, and maintained properly. Even with BMPs, post-development stormwater pollution loadings are still greater than pre-development levels. Minimizing stormwater pollutant loadings from new developments is essential in assuring the success of stormwater retrofitting programs. Otherwise, the desired watershed pollutant loadings will be exceeded and the community's desired ecological goals will not be achieved.

C. Selective Targeting

The extremely high cost of retrofitting older urban stormwater systems makes it essential to carefully evaluate pollutant reduction goals, allocation strategies, and BMP implementation. ***States should establish a priority watershed program which leads to development and implementation of watershed management plans***. Implementation of these long term (15-30 years) plans will be designed to protect or restore the beneficial uses of priority, targeted water bodies.

Within priority watersheds, sub-basins can be targeted based on pollution sources, flooding, and water quality problems. Regional and local stormwater master plans are an essential component of the watershed plan. In these local plans, existing stormwater systems can be targeted for modification to assure that citizens receive the greatest benefit (pollutant load reduction, flood protection) for the dollar. The upgrading of older systems also needs to be coordinated with other planned infrastructure improvements, such as road widenings, and with park, recreation, and urban redevelopment projects .

D. Alternative Controls

Nonstructural BMPs and source controls need to be used extensively to reduce stormwater pollution from already developed areas. For example, street sweepers remove lots of litter, debris, and sediments from paved surfaces even if they can't collect the smaller particles (<60 microns) which contain high concentrations of metals and other pollutants. Prohibiting and eliminating the discharge of wastewaters other than stormwater into storm sewers and other conveyances can also greatly reduce pollutant loadings. These types of controls are especially appropriate in downtown business districts, where other BMPs usually are infeasible, and in certain industrial situations.

Storm drain stenciling.

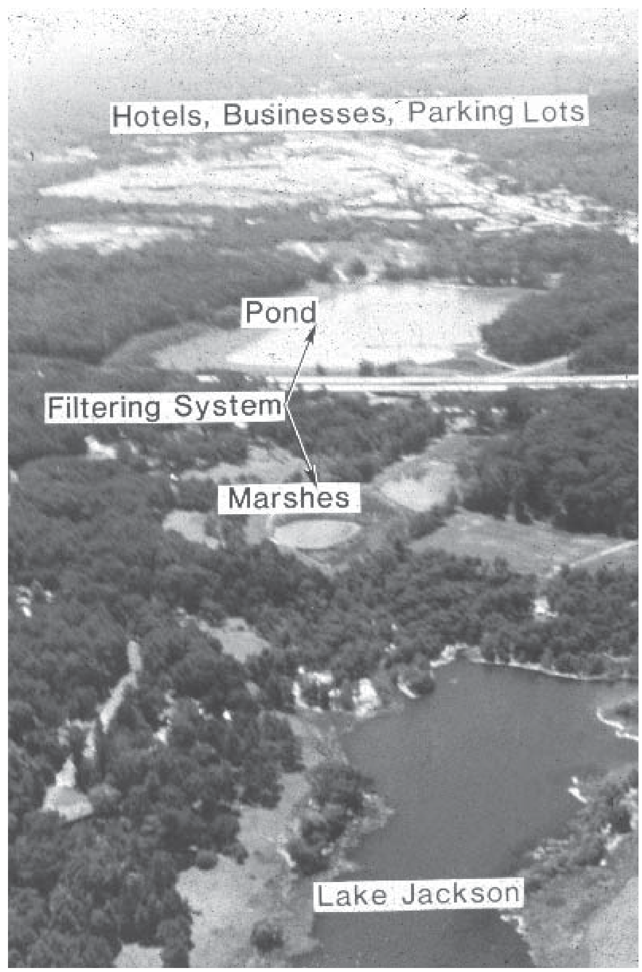
Education programs for the public and for stormwater management professionals also are vital. Citizens, businesses, and practitioners need to understand how their everyday activities contribute to stormwater pollution. For example, citizens should not discard leaves, grass clippings, used motor oil or other material into swales or storm sewers. Yet ***many people believe that storm "sewers" go to the wastewater treatment plant and not to the nearest water body.*** Getting youth and citizen groups involved in storm sewer stenciling projects (Dump No Wastes, Drains to Lake) is an excellent way of reducing dumping of potential pollutants into these conveyances. Equally important are comprehensive training and certification programs for those in the private and public sectors who design, review, construct, inspect, operate, or maintain stormwater management systems.

E. Funding

Even just to solve existing flooding problems, the national cost of improving stormwater infrastructure is gigantic. Yet, local governments already are struggling financially. ***Traditional revenue sources such as property taxes cannot be relied upon to pay for stormwater management***. Alternative funding sources are needed. An excellent example is the stormwater utility - a dedicated source of revenue with fees based on a site's contribution to the stormwater problem.

F. Innovative BMPs

The infeasibility of using traditional BMPs to reduce stormwater pollutant loads in urban areas requires creative and innovative BMPs. ***Regional stormwater systems, which manage stormwater from several developments or an entire drainage basin, offer many advantages over the piecemeal approach that relies upon small, individual on-site systems***. Regional systems can use natural processes, such as extended detention and constructed wetlands, or mechanical processes, such as alum injection,



Lake Jackson regional stormwater system, Tallahassee, Florida.

to reduce stormwater pollutants. They provide economies of scale in construction, operation and maintenance. Regional systems are especially useful in managing stormwater from existing land uses. They need to be a central part of any retrofitting program. They can also be used to provide stormwater management for new development, but this requires excellent planning and an expenditure of funds by the local government or a developer to build the regional system and then get repaid by those who use it. Regional systems are most successful when a watershed approach is used that fully integrates land use, stormwater management, wetlands protection, parks, and recreation/open space.

***Innovative practices which are not land intensive are urgently needed*. *Injecting chemical coagulating agents into storm sewers to enhance flocculation and sedimentation of stormwater pollutants is an example*.** This often may be a better BMP where land for traditional detention basins is unavailable or expensive. Several alum injection systems have been installed in urban areas in Florida to help restore receiving lakes. Concerns over potential aluminum toxicity, however, must still be addressed before this innovative BMP can be fully endorsed.

2.3. Stormwater BMPs and New Development

This section will briefly discuss some key issues of using BMPs to reduce the stormwater impacts associated with new development. These issues include the stormwater program's goals, the setting of performance standards, and the establishment of design criteria for specific BMPs.

2.3.1. Program Goals

The goals of a stormwater management program must be clearly established up front. Until recently, this was a relatively easy task since programs typically were established only to control stormwater peak discharge rates. This is why stormwater management frequently is referred to as "drainage" -- the traditional focus is on draining runoff away from developed property as quickly as possible.

<u>A. Stormwater Quantity Goals</u>

Today, even the goals of stormwater quantity management are changing and broadening. Control of stormwater volume, not just peak discharge rate, is being required in closed basins and for discharges to estuaries. Peak discharge rate control also is evolving - from control of a single frequency storm to multiple frequency storms. ***It is becoming common to control the peak discharge from a 1 or 2-year storm to minimize the erosion of stream channels, in addition to controlling the peak discharges for 10-, 25- and/or 100-year storms for flood control***. Some stormwater management entities such as the Suwannee River Water Management District and the Florida Department of Transportation are requiring control of the "critical storm". This storm creates the biggest difference between pre-development and post-development peak discharge rate and/or volume.

<u>B. Stormwater Quality Goals</u>

The increasing awareness of stormwater quality problems by citizens and elected officials, along with Federal Clean Water Act requirements, is stimulating state and local governments to broaden the objectives of their stormwater programs. ***Today, stormwater management program goals include consideration of stormwater***

quantity, stormwater quality, erosion prevention and sediment control, aesthetic values, stormwater reuse, and even open space and recreational benefits.

Stormwater quality programs need to be implemented within the framework of the federal Clean Water Act. It establishes two types of regulatory approaches to control pollutant discharges. ***Technology-based effluent limitations*** reflect the best controls available, considering their technical and economic achievability. ***Water quality-based effluent limitations*** reflect the water quality standards and allowable pollutant loadings set up by permit (U.S. EPA, 1994).

With respect to stormwater discharges, the latter approach possibly can be developed and implemented through a comprehensive monitoring approach. This not only involves traditional water chemistry monitoring, but also needs to includes sediment chemistry, and an assessment of physical habitat, stream bank erosion, biological community structure, and possibly even whole-effluent toxicity. These techniques are more appropriate than water column chemistry in assessing cumulative, intermittent stormwater impacts.

However, implementing a water quality-based effluent limit permit program for stormwater discharges is nearly impossible because of staffing and technical limitations. The many land use changes occurring in this country create tens of thousands of new stormwater discharges each year. Site-specific analyses to establish water quality-based effluent limitations for so many new discharges simply can't be done. Additionally, there is a sparsity of data on stormwater toxicity and ecological impacts. Therefore, ***nearly all stormwater quality permitting programs are technology-based***.

In 1987, the EPA issued guidance on the development of technology-based stormwater programs and the role of water quality criteria. The guidance recognizes that **Best Management Practices (BMPs)** are the primary mechanism for achieving water quality standards. ***BMPs are control techniques used for a given set of site conditions to achieve stormwater quality and quantity enhancement at a minimum cost*** (Wanielista and Yousef, 1986). The guidance also recommends that state programs should include the following iterative process:

1. Design of BMPs based on site-specific conditions, technical, institutional and economic feasibility, and the water quality standards of the receiving waters.
2. Monitoring to ensure that practices are correctly designed and applied.
3. Monitoring to determine the effectiveness of BMPs in meeting water quality standards and the appropriateness of water quality criteria in reasonably assuring protection of beneficial uses.
4. Adjustment of BMPs when water quality standards are not being protected to a designed level, or evaluation and possible adjustment of water quality standards.

The ultimate water quality goal of stormwater management programs is to protect or restore the beneficial uses of the receiving waters through the proper installation and operation of program-approved BMPs. If beneficial uses are not maintained or restored, additional BMPs need to be implemented and/or the design criteria for current BMPs should be modified to improve their performance.

2.3.2. Program Performance Standards

Whether for BMPs serving new development or for retrofitting, a performance standard must be established so that specific BMP design criteria can be developed. ***The performance standard establishes a technology-based effluent limitation for stormwater treatment systems.***

A. Stormwater Management Goals

Ideally, the basic goal for stormwater systems serving new development is to assure that the post-development peak discharge rate, volume, timing and pollutant load does not exceed pre-development levels. However, this goal usually is unattainable because our current BMPs, either alone or in combination, can not achieve this level of treatment and/or volume control, and because of the limitations imposed by variations in site conditions. This necessitates the establishment of performance standards that can be achieved through the implementation of BMPs.

B. Stormwater Treatment Performance Standards

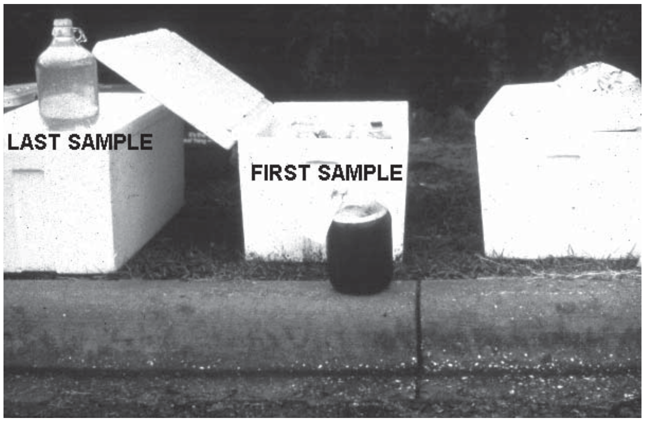
The stormwater treatment programs in Florida, Delaware, and Maryland have established similar performance standards for stormwater systems serving new development. ***They require stormwater systems to achieve at least an 80% reduction in the annual average post-development pollutant loading of Total Suspended Solids (TSS) discharged to fishable/swimmable waters.*** This performance standard corresponds to secondary treatment levels, thereby helping to create greater equity between intermittent stormwater discharges and the treatment requirements for traditional point sources such as domestic and industrial wastewater discharges. Florida's program also sets a 95% removal level for stormwater discharges to sensitive waters such as potable supply waters, shellfish harvesting waters, and Outstanding Florida Waters.

2.3.3. BMP Design Criteria Factors

Once the performance standard is established, design criteria then need to be set for each of the various BMPs that are going to be used for stormwater management. ***This section will briefly review some of the factors that must be considered when setting BMP design criteria.*** The primary factors influencing BMP removal efficiency include rainfall characteristics; the volume of stormwater that is detained, infiltrated, or reused ("treatment volume"); the time needed to recover the treatment volume; the processes used to capture, filter, or assimilate stormwater pollutants; whether the system is on-line or off-line; and site conditions. By analyzing the factors below, an average annual pollutant removal efficiency can be calculated based on the annual mass of pollutants introduced and the annual mass removed.

A. Rainfall Characteristics

An analysis of long-term rainfall records needs to be undertaken to determine the statistical distribution of various rainfall characteristics such as storm intensity and duration, precipitation volume, number of storms, time between storms, etc. ***Unlike flood control, which focuses on large, infrequent storms, effective stormwater treatment generally relies on capturing and treating runoff from small, frequent events that carry the majority of pollutants***. For example, in Florida, nearly 90% of a year's storm events produce one inch of rainfall or less, and 75% of the total annual volume of rain falls in storms of one inch or less (Wanielista, 1977). Also, the average time between storms is an important consideration in designing stormwater management practices (Wanielista et. al., 1991).



Example of first flush runoff from a parking lot.

B. "First Flush" Phenomenon

"First flush" describes the washing action that runoff may have on accumulated pollutants in the watershed. In the early stages of runoff, the land surfaces, especially impervious surfaces like streets and parking areas, are flushed clean by the stormwater. This can result in higher concentrations of some stormwater pollutants, especially particulates, during the early part of the storm (Miller, 1985). However, ***the occurrence of "first flush" depends on many factors, including the pollutant, conveyance system, drainage area, percent imperviousness, rainfall patterns, and location***. For example, in the Pacific northwest, which has frequent, long duration, low volume storms, first flush is much less pronounced. Where a target pollutant is associated with the first flush phenomenon, only this early fraction of the total storm runoff volume must be captured and treated to reach the desired treatment level.

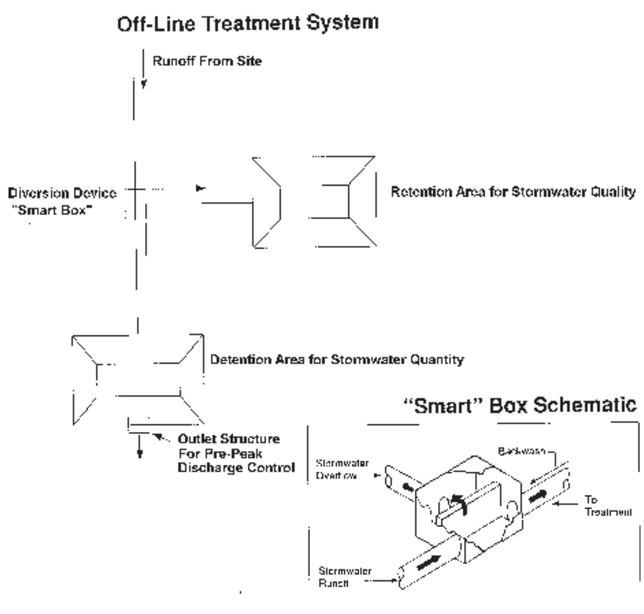
C. Land Use Pollutant Loadings

Stormwater pollutant sources, concentration peaks, and decay functions vary from site to site. Accordingly, ***the typical stormwater pollutant loading from any particular type of land use can vary greatly***. Runoff from residential lands have lower concentrations and loadings of most pollutants when compared to stormwater from commercial land uses or highways. Runoff from streets and parking lots will have higher concentrations of heavy metals and other petroleum associated pollutants. Consequently, setting design criteria for stormwater BMPs must include evaluation of factors such as land use, the pollutants on site, and the characteristics of the drainage basin, such as the soil type, amount of imperviousness, type of stormwater conveyance system, and the length and time of travel.

D. On-line vs. off-line BMPs

On-line BMPs capture all of the runoff from a design storm, temporarily storing it before discharge. They primarily provide flood control benefits, with water quality benefits secondary. However, some on-line BMPs, such as wet detention systems, can do an excellent job of achieving both objectives.

Off-line BMPs divert the runoff "treatment volume" for treatment and isolate it from the remaining fraction of runoff, which must still be managed for flood control. This



SCHEMATIC OF AN OFF-LINE TREATMENT SYSTEM helps to improve treatment efficiency, reduce BMP maintenance, and make maintenance easier.

E. BMP Efficiency and Cost Data

During the past 15 years, many investigations of BMP effectiveness have been performed. Typical information generated often includes the pollutant removal effectiveness of various BMPs, and the costs of BMP construction and operation. A review of Florida BMP investigations (Wanielista and Shannon, 1977) revealed that ***the cost of treatment increases exponentially beyond "secondary treatment" (i.e., removal of 80% of the annual load)***. Therefore, higher levels of treatment are required in Florida only for stormwater discharges to the state's most sensitive water bodies.

F. Site evaluation

The soil types, slopes, geology, water table and other features of a site will greatly influence which BMPs will be most effective. Sandy soils imply using infiltration practices while natural low areas and high water tables offer opportunities for wet detention ponds or constructed wetlands.

3. STORMWATER POLLUTANTS AND REDUCTION MECHANISMS

The key to properly specifying, designing, and operating treatment practices is an awareness of the pollutants in stormwater and an understanding of the biological, chemical, and physical mechanisms that can be used to prevent them from proceeding into receiving waters. Table 2-1 lists the principal mechanisms that have potential to capture, hold, and transform the various classes of pollutants in urban runoff. The most common stormwater pollutants and amelioration mechanisms are summarized below:

1. **Sediment** is solid material that originates mostly from disintegrated rocks, eroded soil, or accumulated organic materials deposited on the land surface. The quantity, characteristics, and causes of the sediment are influenced by many factors including slope, slope length, soil characteristics, and land use, and traffic volume. Sediment particles vary greatly in size and density. ***The settleability of a particular sediment particle depends directly on it's size and density.*** Sediment size and density must be determined to know which BMPs are most appropriate to remove the particles and to build into the stormwater management system appropriate mechanisms to promote the settling of these particles. Some soils, because of their silty, colloidal nature, can almost never be settled once they get into suspension. These soils may require the use of coagulating agents, such as alum or ferric compounds, to remove them from the water. ***Of course, the most effective control method for sedimentation is erosion control--prevent the production of sediment as much as possible.***

2. **Oxygen-demanding substances** include numerous organic materials that are decomposed by microorganisms thereby creating a need for oxygen. Consequently, a stormwater system such as a detention pond must include mechanisms to maintain high oxygen levels and prevent the formation of anaerobic conditions. Oxygenation mechanisms can be natural (such as shallow depths, sufficient length and width to induce wind mixing, and orientation to maximize the opportunities for wind mixing) or mechanical (such as aerators).

3. **Heavy metals** in highway runoff originate from the operation of motor vehicles, atmospheric deposition, and the degradation of highway materials. The most abundant heavy metals in stormwater are lead, zinc and copper, which together account for about 90

TABLE 2-1. Summary of Stormwater Pollutant Removal Mechanisms

MECHANISM	POLLUTANTS AFFECTED	REMOVAL PROMOTED BY
Physical sedimentation	Solids, BOD, pathogens, particulate COD, P, N, synthetic organics	Low turbulence, increased residence time
Filtration	Same as sedimentation	Fine dense herbaceous plants, constructed filters
Soil incorporation	All	Medium-fine texture
Chemical precipitation	Dissolved P, metals	High alkalinity
Adsorption	Dissolved P, metals, synthetic organics	High soil Al, Fe, organics, circumneutral pH (around 7)
Ion exchange	Dissolved metals	High soil cation exchange capacity
Oxidation	COD, petroleum hydrocarbons, synthetic organics	Aerobic conditions
Photolysis	Same as oxidation	High light
Volatilization	Volatile petroleum hydrocarbons, synthetic organics	High temperature and air movement
Biological microbial decomposition	BOD, COD, petroleum hydrocarbons, synthetic organics	High plant surface area and soil organics
Plant uptake and metabolism	P, N, metals	High plant surface area and activity
Natural die-off	Pathogens	Plant excretions, saline water
Nitrification	NH-3	Dissolved oxygen < 2 mg/l, low toxicants, temperature > 5-7 C, circumneutral pH
Denitrification	NO3 + NO2	Anaerobic, low toxicants, temperature > 15 C

percent of the dissolved heavy metals and 90-98 percent of the total metal concentrations (Harper, 1985). ***Except for copper, zinc, and cadmium, the majority of metals are present in particulate form.*** Consequently, very good removal efficiencies (60-95%) can be obtained in properly designed stormwater management practices.

To maximize heavy metal removal in detention designs, designers should provide physical configurations which encourage a gradual reduction in flow velocity to promote particle sedimentation; maximize the flow length from inlets to the discharge point; prevent short circuiting of flows and hydraulically dead zones; and include suitable aquatic plants to promote uptake and removal of dissolved metal species. ***To keep metals bound to sediment, it is important that the sediment pH be kept near 7 and that the sediments be aerobic***. A decrease in pH and, to lesser extent, a reduction in redox potential, will cause metals to become soluble and release from the sediment (Harper, 1985). For this reason, it is important to monitor the accumulation of sediment and decaying organic matter within detention ponds since this can result in lowered pH and possible anaerobic conditions. Failure to properly remove sediments could cause release of accumulated metals into the underlying ground water or into surface waters.

4 **Nutrients**, such as nitrogen and phosphorus, are common constituents of stormwater. They stimulate the growth of algae and other aquatic plants, and contribute to oxygen depletion as these plants decompose. Excessive nutrients accelerate the natural process of eutrophication in lakes and streams. ***Nutrients in stormwater may be either dissolved or particulate, with particulate forms slightly dominating (about 60%)***. Consequently, a stormwater management system, especially a wet detention system, must incorporate provisions for settling to remove particulate forms of nutrients and include nutrient assimilation for dissolved forms. A littoral zone planted with suitable aquatic plants should be concentrated near the discharge point to provide nutrient assimilation. Biofiltration, swale conveyance, sediment sumps, or a perimeter swale and berm system can be used to reduce particulate nutrients.

5. **Increased temperature of stormwater** occurs because urban lands, especially impervious surfaces, are heated on warm days. Runoff stored in BMPs, especially shallow ponds, is also heated by the sun between storms. Proper selection of BMPs is the best way to minimize adverse thermal impacts from stormwater BMP discharges. Galli (1991) ranks the potential of BMPs to raise receiving water temperatures, from least to most serious, as: infiltration basins < extended detention wetlands < extended dry detention ponds < wet detention ponds. Other methods to lessen thermal impacts include using wetland plants, or trees to help shade BMPs, especially pilot channels and outfall channels for extended dry detention ponds. The use of exposed riprap or concrete surfaces for these channels also can be minimized. BMPs also can be oriented to take advantage of prevailing winds, promoting water circulation and cooling.

6. **Increased stormwater volume** associated with the increased imperviousness which accompanies urbanization is now being recognized as a major cause of water body degradation. The increased volume of runoff causes channels and streams to flow at bank full levels more frequently resulting in streambank and bed erosion, and loss of habitat. Additionally, the discharge of greater volumes of runoff to estuaries has led to decreases in their salinity and shifts in biological communities. Reducing stormwater volume is not easy. Nonstructural BMPs to

minimize imperviousness and reduce directly connected impervious area are the most effective. Structural BMPs which help to reduce stormwater volume include infiltration systems, many biofiltration systems, and wet detention stormwater reuse systems.

Although not specifically listed in Table 2-1, ***treatment time is an important factor in the functioning of all mechanisms***. The effectiveness of settling a solid particle is directly related to the time provided to complete sedimentation at the characteristic settling velocity of the particle. Time is also a crucial variable in determining the degree to which chemical and biological mechanisms operate. Chemical reactions and biologically mediated processes all proceed at characteristic rates, which must be implicitly recognized to obtain their benefits in treatment. ***For all of these reasons, water residence time is the most basic variable for applying treatment practice technology effectively***.

An alternative way of looking at the information presented in Table 2-1 is to group features that promote certain specific pollutant control objectives. The following list extracts those features for the most common objectives:

Features That Help Achieve All Objectives

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

Features That Help Achieve Specific Objectives

Phosphorus control:
- High soil exchangeable aluminum and/or iron content
- Addition of precipitating agents

Nitrogen control:
- Alternating aerobic and anaerobic conditions
- Low levels of toxicants
- Circumneutral pH (around 7)

Metals control:
- High soil organic content
- High soil cation exchange capacity
- Circumneutral pH

Organics control:
- Aerobic conditions
- High light
- High soil organic content
- Low levels of toxicants
- Circumneutral pH

The degree of control that the treatment system designer and operator can exert to influence the operation of these various features differs. Fortunately, at least three of the four features that promote all favorable mechanisms (possibly excluding the soil) are under a high degree of control. The additional features that promote the more specific objectives require more intervention (e.g., developing some desired soil condition).

4. STORMWATER MANAGEMENT PRACTICES (BMPs)

The stormwater management tool box contains many tools that can help prevent or correct stormwater problems. The broadening objectives of stormwater management is leading to the development of new tools and the refinement of some of our existing tools. The goals of a stormwater program usually will play a major role in deciding which tools will be selected and used.

Generally, the ***stormwater tool box can be separated into two main drawers: nonstructural controls and structural controls.***

Generally, nonstructural controls are those that can help to prevent stormwater problems, while structural controls are used to mitigate stormwater problems. Until recently, most stormwater programs, because of their focus on flood control, have relied upon structural controls.

Nonstructural controls often are somewhat difficult to implement. Several of them require consideration and control of changes in property (i.e., growth management, land use planning, zoning) - often very controversial topics. ***Nonstructural controls also include "source controls", which are used to limit the types and amounts of potential pollutants that get into runoff***. Many source controls involve modifying or controlling certain aspects of human behavior such as the use of fertilizers, pesticides or household cleaners. Doing so may be very difficult or highly controversial. However, source controls can be very effective, especially in highly urbanized areas, and less costly than structural controls. ***The dilemma for stormwater managers is the effectiveness of nonstructural controls is not well understood yet***.

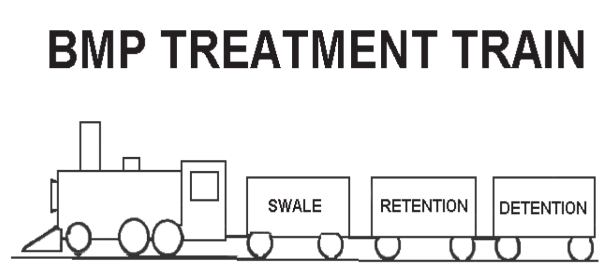
With respect to structural controls, broadening of stormwater management goals often requires reconsideration of the usual BMP design, less emphasis and use of certain practices, changes in preferred alternatives, and greater emphasis on regular maintenance. For example:

- To improve pollutant removal, detention pond design typically must be changed to increase residence time, maximize length of flow through the pond, and include shallow littoral zones planted with appropriate native wetland plants to help remove dissolved nutrients and metals.

- Less emphasis is placed on use of dry detention, which is used widely for flood control. However, dry detention systems provide very low pollutant removal benefits because of very short detention times, bottom discharge controls, and paved channels.

- In many locations, local codes require the use of street curbs and gutters with storm sewers to eliminate ponding of runoff, even for short periods of time. To promote infiltration, thereby decreasing runoff volume and improving pollutant removal, many localities are eliminating this requirement and promoting the use of roadside vegetated swales, especially in low or medium density residential areas.

- ***There is increasing emphasis on the "BMP treatment train" concept, wherein several types of stormwater controls are used together and integrated into a comprehensive stormwater management system***. This is especially true where wet detention ponds are the primary control but are being promoted as a visual and recreational amenity on a project. To help prevent the wet pond from turning into an algae-covered eyesore, swales can be used for conveyance instead of storm sewers, and vegetated littoral zones are added to assimilate nutrients. Increasingly, the use of small, off-line depressional storage areas is being integrated into site plans, usually as part of the site's required open space and landscaping. These can not only reduce pollutants but decrease the overall size



and cost of downstream stormwater system components.

4.1. BMP Selection

Effective operation and minimum maintenance of a stormwater system begins with selection of the most appropriate BMP(s) for the site. Factors which need to be evaluated include:

A. Watershed Area

Infiltration, biofiltration, and filter BMPs generally are more suitable for smaller areas. Pond BMPs typically require a larger drainage area to assure proper operation.

B. Area Required

Adequate area must be available at the site. Many BMPs are land intensive but some can be installed underground, although this increases maintenance difficulties and costs.

C. Stormwater pollutants

Most BMPs are more effective at removing particulate related pollutants. Some BMPs, primarily those with vegetative components, can also reduce dissolved constituents.

D. High Sediment Loading

Many BMPs are highly susceptible to clogging. Pretreatment (BMP Treatment Train) helps to increase effectiveness, reduce maintenance, and extend the life of BMPs.

E. Soil type

Soil permeability has a profound influence on BMP effectiveness, especially for infiltration practices. Also, silty and clayey soils that get into stormwater are much harder to settle than sandy ones.

F. Slope

Steep slopes can restrict the use of several BMPs, especially when water ponding or flow velocity may cause instability or erosion.

G. Water Table Elevation

A crucial factor in the design of all BMPs is water table elevation. Incorrectly estimating the seasonal high water table so it is too close to the bottom can cause BMP failure, decrease effectiveness, and increase maintenance. This is especially true for infiltration or dry detention systems. Wet ponds need high water tables to maintain their permanent pools.

H. Bedrock or Hardpan

Restrictive soil layers or rock can impede downward infiltration of runoff or make excavation for ponds impossible or expensive.

Solution pipe sinkhole in the bottom of an infiltration system.

I. Karst Geology

Fractured limerock geology provides channels for stormwater pollutants to migrate into the ground water. Excavation or the hydraulic head of stored runoff may create sinkholes in the bottom of BMPs creating a direct discharge to ground water.

J. Proximity to Foundations, Septic Tanks, and Wells

BMPs should not be located close to building foundations, septic tanks, or drinking wells. Seepage problems or ground water pollution can result, especially from infiltration practices.

K. Receiving Water

If the stormwater discharge will be to an estuary or other saline habitat, BMPs which reduce stormwater volume need to be considered first. If the discharge is to a water body which supports a cold water fishery or biological community, the potential thermal impacts must be considered in the selection of the most appropriate stormwater BMPs.

L. Water Availability

Water may be needed during the dry season to keep grass or other vegetation alive and continuing to function as a filtering media.

M. Side Effects and Ancillary Benefits

Potential for mosquito breeding or ground water contamination need to be considered, as do opportunities for wildlife use and passive recreation.

N. Public Acceptance

No stormwater system will be maintained if the property owner does not like or approve of its design or the types of BMP used.

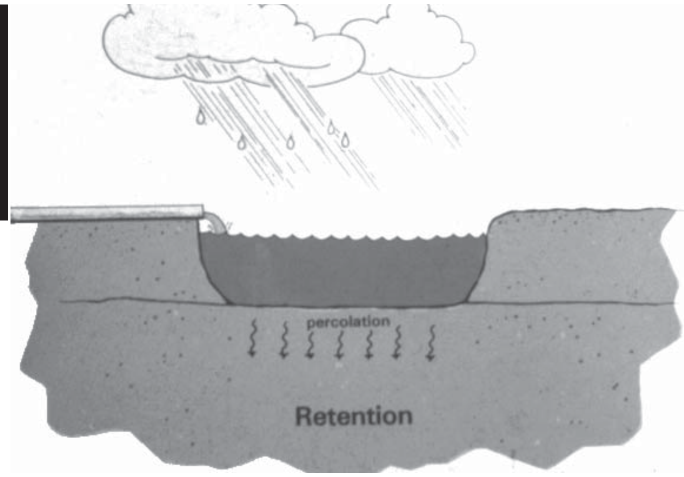
4.2. BMP Fact Sheets

The remainder of this chapter consists of a series of fact sheets on each of the major types of stormwater management practices used to treat runoff. They are presented in the following order:

- Infiltration Practices
  - Infiltration Basin
  - Infiltration Trench
  - Exfiltration Trench
  - Pervious Pavement
  - Modular Pavement
- Detention Practices
  - Dry Detention Basin
  - Extended Dry Detention Basin
  - Wet Detention Basin
- Biofiltration Practices
- Constructed Wetlands
- Filtration Practices

BMP Treatment Train. Runoff is routed off the parking lot through curb cuts, into a swale which conveys stormwater to a raised inlet. A storm sewer transports the runoff to a wet detention pond, all in a landscaped setting. Remember "BMP" does not stand for Big Muddy Pond!

Infiltration Practices



Description

A family of practices in which the "treatment volume" is infiltrated into the soil rather than discharged off-site. Infiltration practices include basins, trenches, dry wells, pervious pavement, and, to a certain extent, swales, which will be considered a biofiltration practice in this handbook.

Purpose

Infiltration practices are used for two primary purposes: reducing the total volume of stormwater runoff, and reducing the stormwater pollutant loading discharged off-site.

Pollutant Removal Mechanisms

The primary "treatment" mechanism is the infiltration and evaporation of runoff. This reduces the total volume of stormwater leaving the site, thereby reducing the total pollutant loading. Ancillary benefits of reducing stormwater volume include a decrease in stream channel erosion and loss of stream habitat.

Pollutant removal occurs as runoff passes through the soil profile and/or the vegetation root mass. Pollutants are trapped, bound, or decomposed in the vegetation, its roots, and in the pore spaces between the soil particles, while runoff passes into the ground. Soils must have an appropriate infiltration rate, contain sufficient organic matter, and maintain aerobic conditions to minimize migration of pollutants into the ground water.

Expected Stormwater Quantity and Quality Performance

Infiltration BMPs are highly effective in reducing total stormwater volume. This helps to reduce peak discharge rates, downstream channel erosion, and downstream water elevations. The infiltrated water also help to preserve stream base flow.

Stormwater treatment effectiveness depends primarily on whether the infiltration practice is on-line or off-line, and on the sizing criteria used to design the facility. When designed as off-line BMPs, infiltration practices remove 100% of the stormwater pollutant loading for all of the runoff which is infiltrated. Total annual pollutant load reduction depends on the volume of annual runoff which is diverted into the BMP and infiltrated into the ground.

On-line infiltration systems will have lower treatment efficiencies than off-line systems.

Expected annual average pollutant removal efficiencies of on-line systems are :

Total Suspended Solids	75%	Total lead	50%
Total Phosphorus	50%	Total zinc	65%
Total Nitrogen	40%, but highly variable	Total copper	25%
COD	40%		

Limitations on Use

- Require porous soils, such as sands and gravels, to allow infiltration of runoff within desired time.
- Not suitable if soils have 30 percent or greater clay content or 40 percent or greater silt/clay content.
- Not suitable in areas with high water tables, shallow depth to highly impervious strata such as bedrock or clay soils.
- Not suitable on fill sites or steep slopes.
- Risk of ground water contamination, especially in coarse sandy soils and karst geology.
- May not be appropriate at sites where spills of hazardous materials may occur.

Operation, Maintenance, and Management Needs and Obligations

Retention basin with soggy bottom because it doesn't infiltrate the runoff within the design time.

■ Operation

Infiltration practices all depend on the ability of stormwater to pass through the vegetation and soil into the ground. Therefore, long term operation of the practice depends on maintaining its permeability.

The primary causes of infiltration system failure include:

- inadequate soil investigation,resulting in poorly designed systems that do not percolate.
- inaccurate estimation of the soil infiltration rate at the bottom of the proposed facility.
- premature use of facility before contributing area is stabilized.
- improper construction, resulting in soil compaction or sedimentation.
- high sediment loadings or a lack of maintenance, leading to clogging.

■ Maintenance

The frequency and need for maintenance will depend primarily on the loading of particulates and whether pretreatment practices have been used. Maintenance activities will include:

- Removal of accumulated solids.
- Mowing and removal of vegetation.
- Vegetative stabilization of eroding sides or bottom.
- Rototilling, disking, or aerating the bottom or bottom vegetation.
- Clearing materials that have accumulated in the discharge structure.
- Cleaning pretreatment BMPs (i.e., swales, sediment sumps) so they can continue to protect the infiltration practice.

■ Management Needs and Obligations

- Inspect the facility semiannually (just before the wet season and at the end of it) and after large storms. If there is still water in the BMP after 72 hours (or after 24-36 hours for vegetated systems), it is time to clean it and restore its percolation capacity. Cleanout frequency will depend on whether the practice is on-line or off-line, vegetated or not vegetated, its design storage capacity, sediment loading, and use of pretreatment BMPs.
- Eroding sides or bottoms need to be revegetated as soon as possible.
- Revegetate the contributing area where needed to stabilize and reduce generation of particulates.

Recommendations to Assure Proper Operation, Maintenance and Performance

1. One of the most difficult aspects of designing infiltration practices, and the key to proper operation, is obtaining reliable information about the actual infiltration rate of the soil where the BMP will be constructed. To determine the infiltration rate, recommendations include:
   - Use a conservative estimate and a safety factor.
   - Measure infiltration rates at the actual location where the BMP is to be sited.
   - Since soil characteristics, including infiltration rate, change with depth, it is crucial that the measurements be made at the depth of the design elevation of the bottom of the practice.
   - Infiltration rates should be determined by mass balance field tests, if possible. If field tests are not possible, then infiltrometer tests should be used. Lab permeability tests are a third option. In either of these latter two tests, the design infiltration rate should be half of the lowest measured rate.

2. To minimize the potential for ground water contamination, be sure that the bottom of the infiltration practice is at least four feet above the seasonal high ground water elevation. Be sure to include consideration of ground water mounding.

3. Do not use infiltration practices for erosion and sediment control during construction.

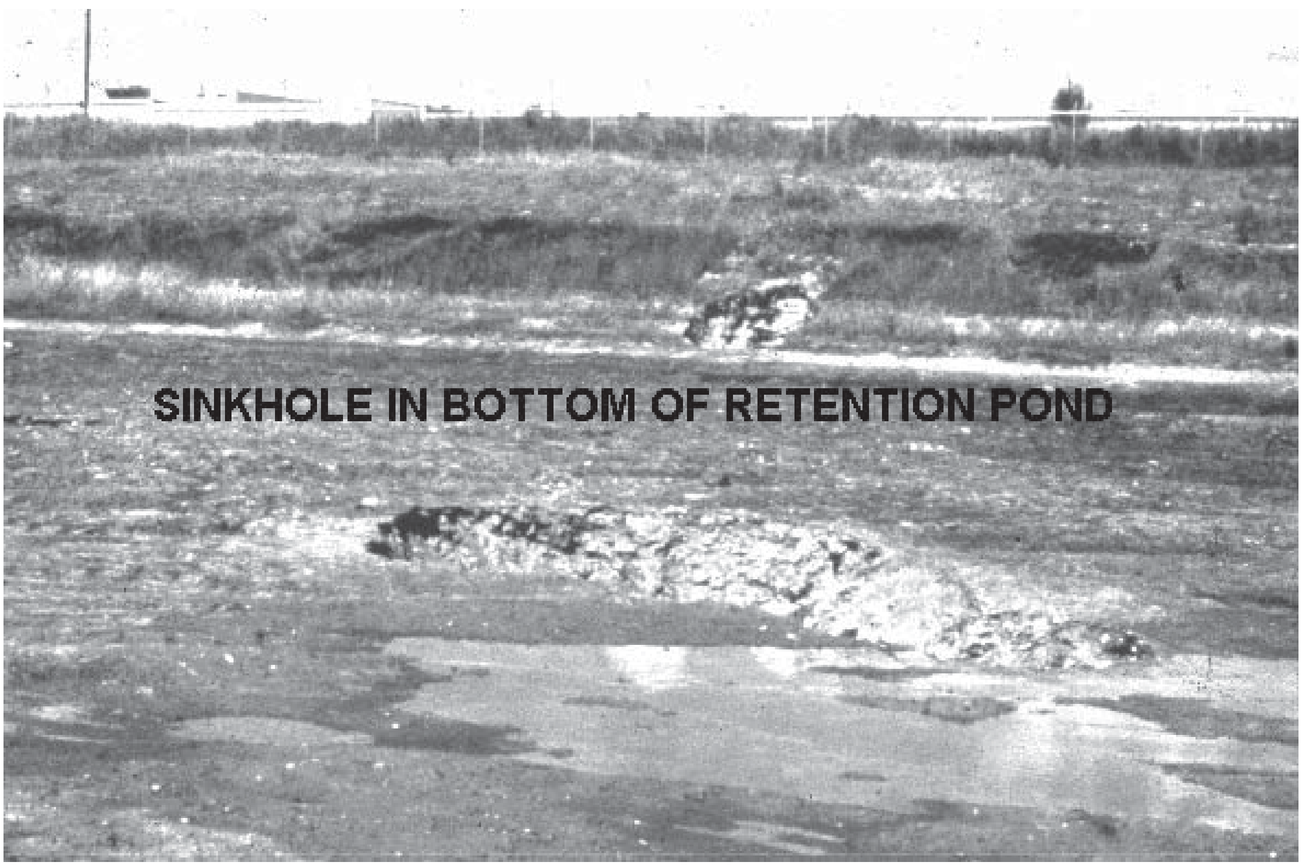
4. Do not place infiltration systems into operation until their contributing drainage area is completely stabilized.

5. Use pretreatment practices such as swale conveyances and sediment sumps to reduce sediment loading and potential clogging.

6. Underground systems must include pretreatment BMPs and an observation well to allow easy determination of whether runoff is percolating within the design time.

7. Include a maintenance access that lets O&M activities get done without moving heavy equipment onto the infiltration area.

8. Bedrock should be at least four feet beneath the bottom of the practice. In those parts of the country with fractured bedrock or where limestone is at or near the land surface, special precautions must be taken to prevent ground water contamination. This is especially true in "Karst Sensitive Areas" where sinkhole formation is prevalent. In these types of areas, a site specific hydrogeological investigation needs to be undertaken including geologic borings wherever infiltration practices are proposed. Infiltration practices in these areas should include several small off-site areas, swale conveyance for pretreatment, be as shallow as possible, be vegetated with permanent cover such as sodded grasses, and have flat bottoms to keep the runoff spread out across the entire infiltration area.



Retention basin built in area of Karst geology.

8. Construction Recommendations: To protect the natural infiltration rate and minimize potential clogging, special precautions need to be taken during construction including:

- If possible, schedule construction so it does not occur during the rainy season and does occur during the vegetative growing season.
- Infiltration areas should be well marked in the field and heavy equipment and sediment kept away from them.
- Construction should be overseen by someone who is trained and experienced in the installation of infiltration practices and who is knowledgeable about their purpose and operation.
- The design team should inspect the exposed soil after excavation to confirm that soil conditions are as expected and are suitable. If they are not, work should stop and the situation should be analyzed to determine whether or not design or construction changes are necessary to ensure success.
- If possible, build the facility without driving heavy equipment over the infiltration surface as this will compact the soil and reduce the infiltration rate. Any equipment driven on the surface should have extra wide, low pressure tires.
- During construction, place excavated material at least 10-15 feet away from the infiltration area.

Sediment from construction activities can quickly clog an infiltration basin.

- Construction of the infiltration practice should not begin until after the site has been completely stabilized. If this is not possible, then:
  - Diversion berms should be placed around the perimeter of infiltration areas to divert runoff and sediment away from them during the construction phase of a project.
  - The facility should not be excavated to final grade until after the contributing drainage area is stabilized. Leave one foot of native soil which can be removed in layers as it clogs while construction is occurring.
  - Excavate infiltration areas using light equipment and construction procedures which minimize compaction.
- After final grading, the infiltration surface area should be deeply tilled to provide a well aerated, highly porous surface texture.

A retention basin which has been recently tilled to help restore its infiltration capabilities.

Infiltration Basin

Description

A surface area used to temporarily store runoff for a selected design storm or specified treatment volume. Storage volume is recovered when the runoff percolates into the soil or evapotranspires. Infiltration basins may be made by either excavating soil or by building an embankment.

Pollutant Removal Mechanisms

- Percolation of runoff reducing stormwater volume discharged off-site.
- Filtering and adsorption of pollutants by the vegetation, roots, and soil profile.

Advantages

- Can be integrated into a site's open space and landscaping helping to increase aesthetics.
- Area can be used for ancillary purpose, such as recreation, between storms .
- Surface systems are more easily inspected and maintained.

Disadvantages

Land needed for the basin can be expensive and prevents this area from being used for other development related purposes.

Operation, Maintenance, and Management Needs and Obligations

■ Operation

Successful operation depends on maintaining the percolation rate of the basin's floor and side slopes. To minimize the potential for ground water contamination, and to naturally help maintain percolation rates, vegetation such as grasses should be planted and maintained on the basin floor and side slopes.

■ Maintenance

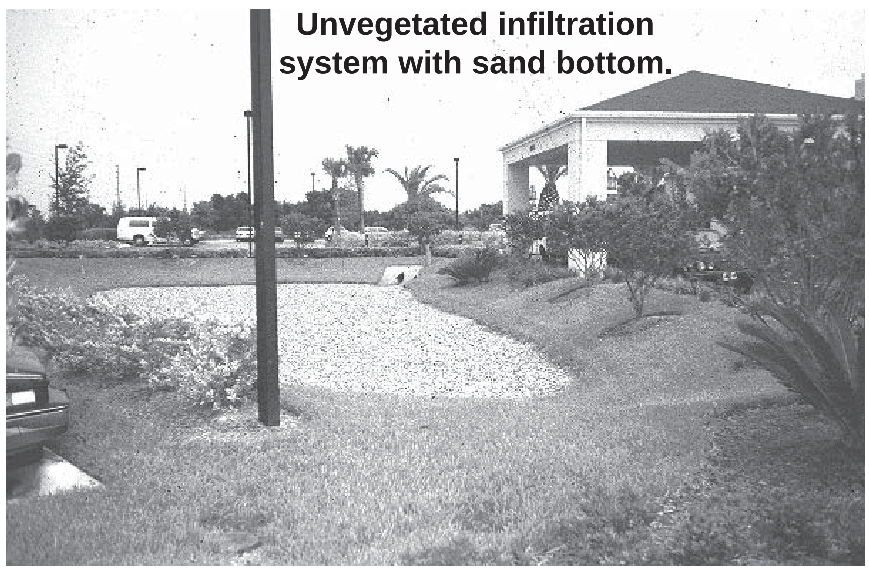
Activities necessary to maintain the basin's function include:

- Removal of accumulated solids. Ideally, these are trapped in a pretreatment settling forebay to minimize the need to disturb the basin's vegetation. In non-vegetated basins, sediments should be removed from the basin when its floor is dry and after the accumulated sediments have cracked and separated from the bottom. Hand raking and removal is recommended, if possible, to minimize compaction. In vegetated basins, the grass often will grow up through sediment deposits unless they are extremely heavy.

Infiltration system vegetated with grass.

- Mowing and removal of vegetation. The use of low growing grasses is recommended to minimize mowing frequency.

- Fertilizers should only be used if absolutely necessary.



Unvegetated infiltration system with sand bottom.

- Vegetative stabilization of eroding sides or bottom.

- In vegetated basins, the grassed floor should be aerated annually.

- Rototilling or disking the bottom in non-vegetated basins. Tilling is required periodically (at least once annually and perhaps more often) to help restore the natural infiltration capacity. All accumulated sediment must be removed first. Light tractors with rotary tillers or disc harrows can be used, followed by use of a levelling drag. After tilling, the basin floor should be level, smooth, and free of ridges and furrows to ease future removal of sediments. In northern climates, the basin surface may be very porous in the spring due to the effects of freeze and thaw. Infiltration capacity will diminish rapidly afterwards so tilling should be scheduled for late spring or early summer to help restore percolation.

- Clearing materials that have accumulated in the discharge structure.

■ Management Needs and Obligations

Inspect semiannually and after large storms to assure proper percolation, prevent erosion, measure sediment accumulations, and assure proper vegetation growth. Signs that the basin is not infiltrating as designed include a "soggy" bottom, death of grass cover, or invasion by cattails or other wetland type vegetation. A simple "staff gage" made from a one inch pipe driven into the ground can be used to measure sediment depths.

Recommendations to Assure Proper Operation, Maintenance, and Performance

1. See recommendations for "Infiltration Practices".

2. Use energy dissipation at inlet to minimize erosion.

3. Side slopes of at least 3:1 for safety, and for ease of mowing, although 4:1 is optimal.

4. Provide dedicated access to the basin bottom for maintenance vehicles.

5. Construction recommendations:

- Follow all of the construction recommendations under "Infiltration Practices".

- To maximize opportunities for infiltration, it is crucial that the basin's floor be evenly graded with a zero slope. If the bottom is uneven, these low spots will remain under water too long and may become chronically wet.

- Since some compaction will occur during excavation and construction, deeply till the bottom of the infiltration surface after final grading or excavation.

- Stabilize with vegetation within one week after construction. Vegetation not only helps to prevent erosion, provide filtration and uptake stormwater pollutants, but the roots help to naturally maintain the soil's infiltration rate. The condition of the newly established vegetation should be checked several times during the first few months. Remedial actions such as reseeding, sodding, fertilization, or irrigation should be taken whenever necessary.

Clogged infiltration basin. Standing water creates an aesthetic and mosquito problem.

Infiltration Trench

Description

A shallow excavated trench, usually two to ten feet deep, backfilled with a coarse stone aggregate, allowing for temporary storage of runoff in the voids between the aggregate material. Trenches can be located on the surface or below the ground. Surface trenches receive sheet flow runoff directly from adjacent area, usually after the runoff flows over a grass buffer. Underground trenches receive runoff from storm sewers and must have pretreatment inlets.

Pollutant Removal Mechanisms

- Percolation of runoff reducing stormwater volume discharged off-site.
- Filtering and adsorption of pollutants by the soil profile.

Advantages

- Require less land area than do surface basins.
- One of the few BMPs that can be used when land area is limited and can be fit into highway medians, site perimeters, and other unused areas of a site.

Disadvantages

- Difficult to monitor their continued performance, especially if observation wells are not included.
- Can become clogged fairly easily and very difficult to unclog, especially underground trenches.

Operation, Maintenance, and Management Needs and Obligations

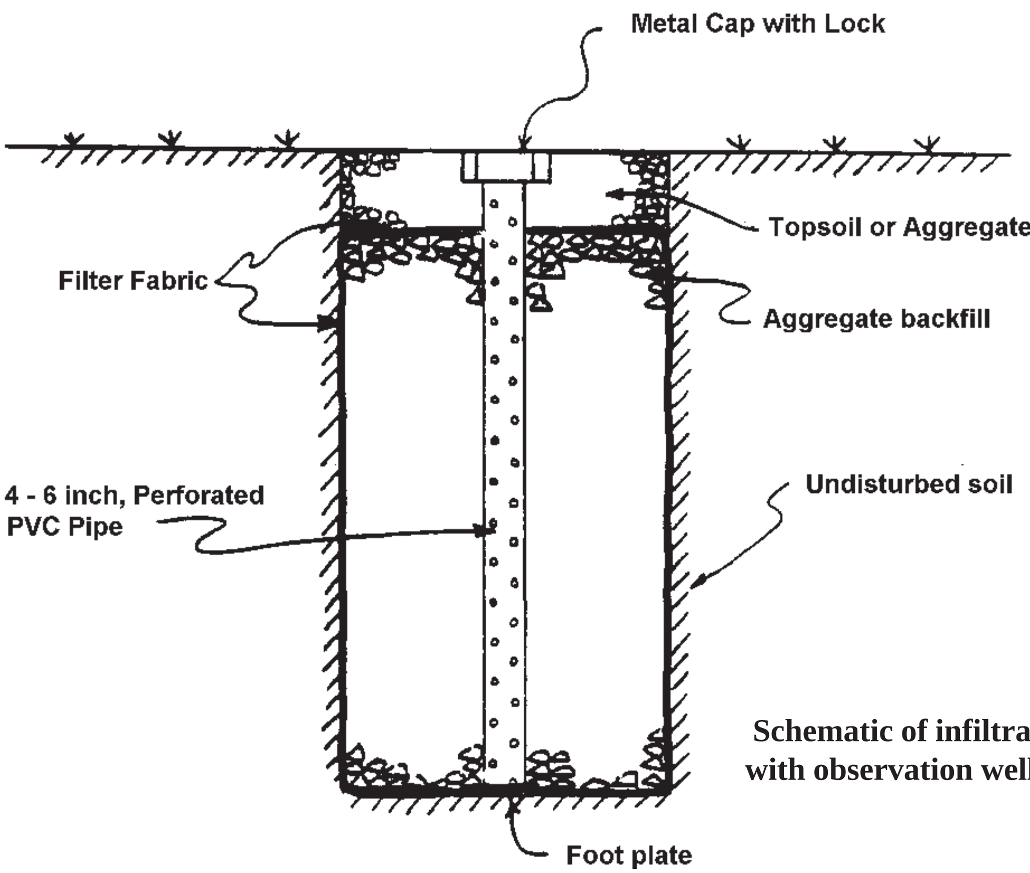
- Operation

Successful operation depends on maintaining the percolation rate of the trench's sides and bottom. The keys to assuring successful long term performance are accurate estimation of the percolation rate, proper construction, pretreatment, off-line design, and maintenance accessibility.

■ Maintenance

Activities necessary to maintain the trench's function include:

- Regular removal of accumulated solids from the pretreatment BMPs to prevent them from moving into the trench.
- Removing sediment buildup in the stone aggregate. This can involve monitoring and removal of sediments within the top foot of aggregate or allowing sediments to penetrate deeper into the trench necessitating removal and replacement of much of the stone aggregate. The former option is preferred.



Schematic of infiltration trench with observation well.

■ Management Needs and Obligations

The observation well needs to be monitored periodically. For the first year after construction, the well and pretreatment BMP should be monitored monthly after a storm during the rainy season and quarterly in the dry season. A log book should be maintained by the responsible maintenance entity and include information such as the date, water level, date of last rainfall, and calculation of the drawdown time. Once the trench's performance characteristics have been documented, the monitoring schedule can be reduced until the performance data indicates a reduction in percolation rate.

Recommendations to Assure Proper Operation, Maintenance, and Performance

1. Accurately estimating the trench's infiltration rate is crucial to successful operation. Whether infiltration primarily occurs through the trench bottom or sides will depend on the elevation of the water table and soil properties.

2. To minimize the potential for ground water contamination, the bottom of the trench should be at least four feet above the seasonal high ground water elevation. Don't forget to include consideration of ground water mounding when setting the elevation of the trench bottom.

3. Pretreatment is essential to minimize sediment and organic matter loading thereby reducing the potential for the stone filled trench to become clogged.

4. A 4 or 6 inch diameter observation well with locking cap must be included to allow evaluation of performance and the infiltration rate over time.

5. <u>Construction recommendations:</u>

- Follow all of the recommendations under "Infiltration Practices".

- Timing - The trench should not be constructed or placed into service until all of the contributing drainage area is completely stabilized. If the trench is constructed prior to drainage area stabilization, then the trench should be covered with heavy plastic to prevent any inflow until stabilization is completed.

- Erosion and sediment control - Special care must be taken to prevent soil from getting into the trench between the aggregate and the geotextile fabric.

- Excavation - The trench should be excavated using a backhoe or trencher equipped with tracks or oversized tires. Normal rubber tires should be avoided since they compact the subsoil and reduce infiltration capability. For the same reason, bulldozers or front-end loaders should not be used unless they are equipped with extra-wide treads ("low pressure treads"). Excavated materials should be kept at least 15 feet away from the trench to avoid backsliding and cave-ins.

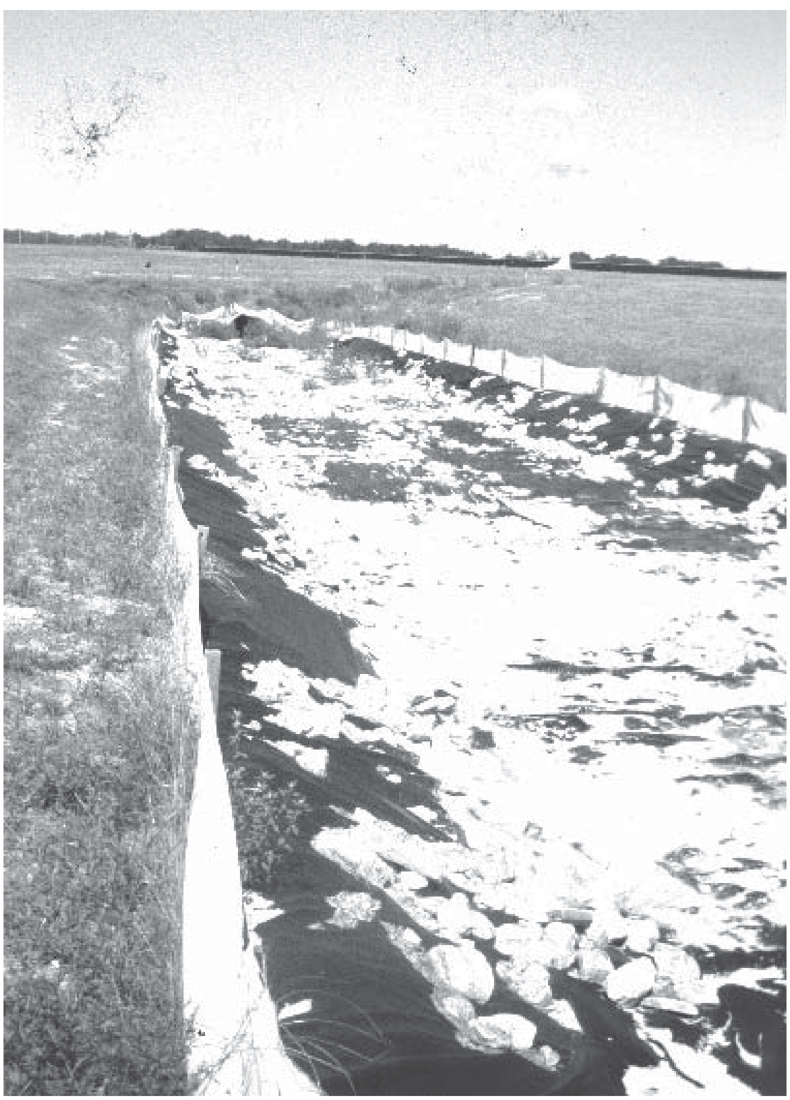
- Geotextile fabric - Once the trench is excavated, the bottom and sides should be lined with an appropriate geotextile fabric to prevent upward piping of underlying soils. Before installing the fabric, inspect the bottom and side walls of the facility for any protruding objects, like tree roots, that may puncture the filter fabric. Care should be taken in selecting the proper kind of fabric as available brands differ significantly in their permeability and strength. When cutting the fabric, be sure the length and width are sufficient to conform to the trench's dimensions and allow a 12 inch minimum top overlap. If more than one roll of fabric is needed, the upstream roll should overlap at least 2 feet over the downstream roll to provide a shingled effect.

- Unstable excavation sites - Vertically excavated walls may be difficult to maintain in areas where the soil moisture is high or where soft or cohesionless soils predominate. These conditions may require laying back the side slopes or using trench safety procedures. Trapezoidal excavation may result when laying back the side slopes creating a need to carefully back fill the space between the filter fabric and the excavation sides. Natural soils should be placed in these spaces at the most convenient time during construction to assure fabric conformity to the final side dimensions. Trenches over four feet deep require shoring pursuant to OSHA regulations.

- Stone aggregate - Clean, washed stone aggregate should be placed in lifts and compacted with plate compactors. Soft stones such as limestone or bluestone aggregates should be avoided. A maximum loose lift thickness of 12 inches is recommended. The compaction process ensures fabric conformity to the excavation sides, thereby reducing potential for soil piping, fabric clogging, and settling problems.

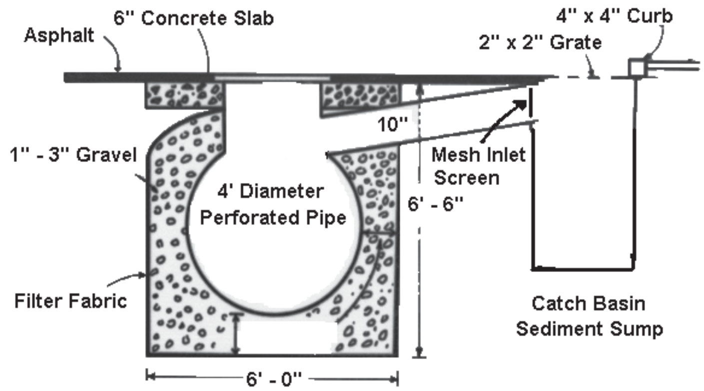
- Covering - Once the stone aggregate is placed, the filter fabric needs to be folded over it to form a minimum 12 inch longitudinal overlap. The desired fill soil or stone aggregate should be carefully placed atop the fabric so as to maintain the overlap.

- Operation - The trench should remain covered until all of the contributing drainage area is completely stabilized.



Infiltration trench covered with plastic, upon which sediment has accumulated, to prevent sediment entry during construction.

Exfiltration Trench



Description

An infiltration trench in which the runoff (treatment volume) is stored in a perforated or slotted pipe, and percolates out through the surrounding gravel envelope and filter fabric into the soil.

Pollutant Removal Mechanisms

- Percolation of runoff reducing stormwater volume discharged off-site.
- Filtering and adsorption of pollutants by the soil profile.

Advantages

Similar to infiltration trenches, except they can also be placed beneath paved surfaces such as parking lots and streets.

Disadvantages

- Difficult to monitor their continued performance, requiring regular visual inspection of the inside of the pipe to determine accumulation of sediments and other materials. Observation wells may not be as useful as for infiltration trenches.
- Can become clogged fairly easily, and they are very difficult and expensive to unclog.

Operation, Maintenance, and Management Needs and Obligations

■ Operation

Successful operation depends on maintaining the percolation rate of the trench's sides and bottom. The keys to assuring successful long term performance are accurate estimation of percolation rate, proper construction, pretreatment, off-line design, and maintenance accessibility.

■ Maintenance

Activities necessary to maintain the trench's function include:

- Regular removal of accumulated solids from the pretreatment BMPs to prevent them from moving into the trench.

- Implementation of source controls, such as street sweeping, landscaping practices, and other good housekeeping practices, which reduce the generation of sediments.
- Removing sediments and other organic matter that accumulates within the exfiltration pipe.
- Pipes should be inspected quarterly for the first year to determine how quickly materials accumulate in them. Accumulated materials can be vacuumed out with a vactor. High pressure cleaning of the holes or slots in the pipes can help to reduce clogging.
- Removing sediments which accumulate within the aggregate envelope, with possible replacement of aggregate necessary if sediments aren't removed from the pipe.

■ Management Needs and Obligations

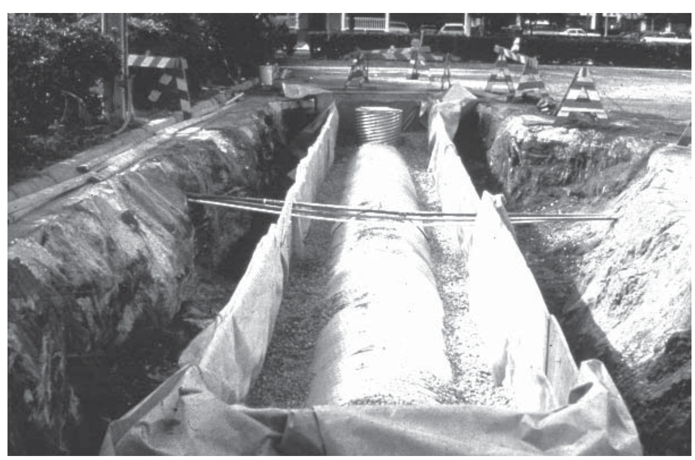
The exfiltration system needs to be monitored periodically. For the first year after construction, the pipe should be monitored quarterly. The pretreatment BMP should be checked monthly during the rainy season and quarterly in the dry season. The observation well, included to monitor water levels in the surrounding gravel envelope, should be monitored after storms monthly during the rainy season and quarterly in the dry season. A log book should be maintained by the responsible maintenance entity and include information such as the inspection date, date and amount of last rainfall, visual observations of the pretreatment BMP and pipe, water level, and calculation of the drawdown time. Once the trench's performance characteristics have been documented, the monitoring schedule can be reduced until the performance data indicates a reduction in percolation rate.

Recommendations to Assure Proper Operation, Maintenance, and Performance

1. Follow all of the recommendations for "Infiltration Trenches".

2. When estimating the design exfiltration rate, Wanielista *et. al.* (1991) concluded:

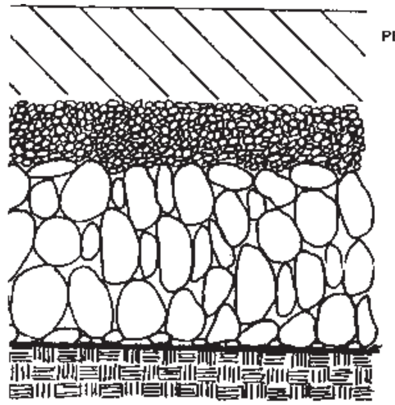
- Permeability of the parent soil is not the limiting exfiltration rate.
- The limiting exfiltration rate is set by the geotextile filter fabric not the soil.
- A maximum rate of 0.5 inch/hour should be used if infiltration is assumed to occur through both the sides and bottom of the trench.
- A maximum rate of 1.0 inch/hour should be used if infiltration is assumed to occur only through the trench's sides.



3. <u>Construction recommendations:</u>

- Follow all of the recommendations for "Infiltration Trenches".

Pervious Pavement



Description

A pavement with traditional strength characteristics but which allows rainfall and runoff to percolate through it rather than running off.

There are two types of pervious pavements - porous asphalt and pervious concrete. Porous asphalt consists of an open graded coarse aggregate held together by asphalt with sufficient interconnected voids to provide a high rate of permeability. Pervious concrete is a discontinuous mixture of Portland cement, coarse aggregate, admixtures, and water which allow for passage of runoff and air. Both types of pervious pavements omit most or all of the fine aggregate typically used in conventional pavements.

Pollutant Removal Mechanisms

- Percolation of rainfall and runoff through the pavement into the underlying aggregate storage reservoir and ultimately into the soil.

Advantages

- Reduces site imperviousness thereby reducing stormwater volume and peak discharge rate.
- Generally, ground water recharge rates are slightly higher under pervious pavement than under natural conditions because vegetation is absent thereby reducing transpiration of soil water.
- Overall construction costs may be reduced because of the reduction or elimination of storm sewers, inlets, and traditional stormwater practices such as detention or retention areas.
- Pervious pavements reduce hydroplaning and skidding by up to 15%.
- Water puddles less on pervious pavement since it moves rapidly into the underlying aggregate reservoir. Besides allowing people to walk through parking lots without getting their feet wet, this also reduces headlight reflection off the surface and makes pavement markings more visible.

Disadvantages

- The major disadvantage is the tendency for pervious pavement to clog. This can occur as a result of improper batching, placement, finishing, and, most commonly, lack of maintenance. Once clogged, it is very difficult and expensive to rehabilitate, often requiring complete replacement.

- Another concern related to failure of pervious pavements is the lack of experience many pavement engineers and contractors have with these pavements. Proper design, batching, pouring, and finishing are essential to the successful use of pervious pavements. Both porous asphalt and pervious concrete require a very high level of workmanship and special procedures to assure that they retain their porous qualities.
- Spills of gasoline or other potentially hazardous materials can lead to soil or ground water contamination and may break down the asphalt binder to greater depths than in conventional pavements. Spills must be immediately vacuumed, followed by a jet washing.
- In areas with long duration rainfalls, such as the Pacific Northwest, anaerobic conditions may develop in the underlying soils since the soils are unable to dry out between storms. This can prevent aerobic bacteria from reducing organic pollutants. Additionally, the wet subgrade soils may not support the design load.

Improper batching at Florida Dept. of Environmental Protection parking lot necessitated replacement of pervious concrete section.

Operation, Maintenance, and Management Needs and Obligations

- Operation

Successful operation depends on maintaining the permeability of the pavement surface. This begins with proper design and construction and is assured over time by proper maintenance.

- Maintenance

Activities necessary to maintain the performance of pervious pavements include:

- "Good housekeeping" practices by the users to minimize the production and transport of particulates onto the pervious pavement. This includes vegetative stabilization of adjacent areas which may erode and become a source of sediments.

- Routine maintenance to remove debris that is too coarse to be washed through the pavement.


Pressure cleaning the FDEP pervious parking lot.

- Regular vacuuming with a vacuum street sweeper to remove particulates that are fine enough to be carried into the pavement but too large to pass through, thereby causing clogging of the void spaces. The frequency of vacuuming will depend on factors such as the amount and type of traffic, and the sources and loadings of particulates.

- High pressure jet hosing on an annual basis to "deep clean" the voids and help restore permeability.

- Management

- All pervious pavements should be inspected several times in the first few months after construction to assure that they are working correctly and to make sure that they were installed properly. Inspections should be conducted after storms to check for surface ponding that may indicate local or widespread clogging. Additionally, the pavement should be checked for the first six months for raveling (dislodging of surface aggregate) or severe rutting.

- The surface should be visually inspected on a routine basis, especially after a prolonged storm event, for evidence of debris, ponding of water, oil dripping accumulations, clogging of pores, and other damage. Debris should be removed periodically to minimize accumulations. If ponding or clogging is noticed, then a maintenance program needs to be implemented. First, a vacuum street sweeper should be used. If ponding continues to persist, steam cleaning with a biodegradable cleaner should be performed, followed by vacuum sweeping.

- If pervious pavement continues to clog after vacuuming and steam cleaning, rehabilitation or replacement of a section or all of the pavement may be needed. Clogged pervious concrete pavements have been successfully restored by drilling holes, 0.25 inch in diameter on one foot centers. Clogged porous asphalt sections have been similarly restored. If clogging continues, sections of pervious concrete can be saw cut and removed. Six to twelve inches of subbase should be replaced with clean, coarse sand or crushed stone, then proof-rolled, followed by a new layer of pervious concrete.

Recommendations to Assure Proper Operation, Maintenance, and Performance

1. Only designers, engineers, and contractors experienced in the placement of pervious pavements should be used. Otherwise, the services of an experienced consultant should be obtained.

2. Proper design is essential. The following steps should be taken to ensure proper design:

- Determine the suitability of the site for the use of pervious pavement. Examine the soils, slopes, and projected use of the site including the expected traffic intensity.

- Sample and test the site's soils to determine their permeability and load carrying capacity. If permeability is marginal, ways to augment percolation (such as perforated underdrains) should be evaluated. Since pervious pavements distribute the loads over a large area, uniformity of subgrade support, rather than strength, is the major criteria of a suitable subgrade. The presence of silts and clays that are highly compressible, lack cohesion, or expand when wet can create problems. These soil conditions must be analyzed individually for their support values and modified or replaced when necessary.

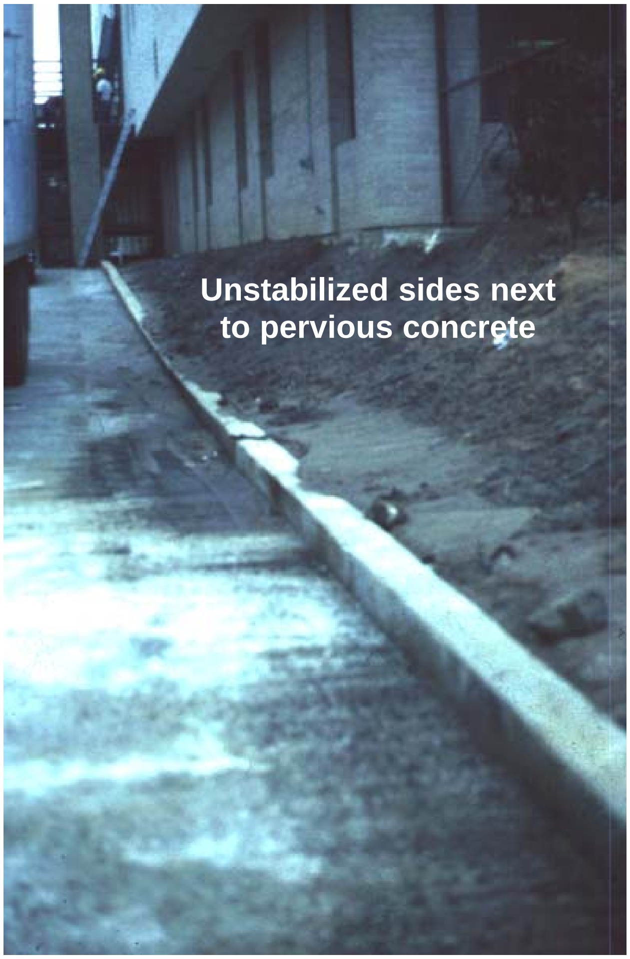
- In frost penetrates deeper than the thickness of the pavement and reservoir courses, and the subgrade soil has the potential for frost heaving, additional thickness must be added to the reservoir base course to extend it below the frost line to allow for adequate drainage.

- Use specifications such as those of the Franklin Asphalt Research Laboratories or found in the Portland Cement Pervious Pavement Manual to determine the appropriate thickness of the pervious pavement system, including its pavement course, filter course, and reservoir course. The thickness of the reservoir course will also depend on the desired storage volume.

- Prepare specifications for materials, product installation, testing, and maintenance. Consult literature from the Franklin Asphalt Research Laboratories or the Portland Cement Pervious Pavement Manual for example specifications.

3. Construction recommendations:

- To preclude premature clogging and/or failure of pervious pavements, they should not be placed into service until the entire contributing surface drainage area has been completely stabilized.



- Clearly mark the planned area for pervious pavement to prevent heavy equipment from compacting the underlying soils.

- Install diversions to keep runoff off the area until the pervious pavement is in place.

- Excavate the subgrade soil using equipment with tracks or oversized tires to minimize compaction.

- Once excavation is complete, the bottom and sides of the stone reservoir should be lined with an appropriate geotextile filter fabric to prevent upward piping of underlying soils. Be sure the fabric is placed flush with at least a 2 feet overlap between rolls. Note that the filter fabric is not used for pervious concrete pavements.

- Clean, washed stone aggregate should be placed in lifts and lightly compacted with plate compactors.

- Porous Asphalt Surface Course - Before placement, be sure that the asphalt mix meets the desired specifications. Lay the asphalt in one lift directly over the aggregate base course but only when the air temperature is above 50^{o} F and the laying temperature is between 230^{o} and 260^{o} F. Roll the asphalt when it is cool enough to withstand a ten-ton roller. One or two passes by the roller normally provides proper compaction. More rolling could cause reduction in the surface course porosity. After final rolling, all traffic should be kept off the porous asphalt area for at least one day to allow proper hardening.

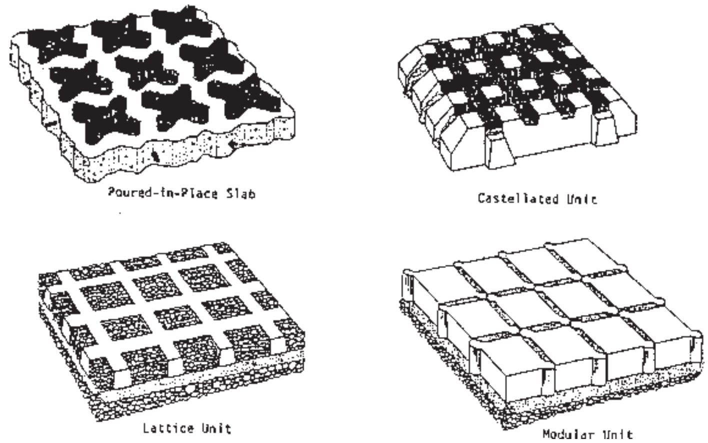
- Pervious Portland Cement - Carefully follow the specifications and guidance set forth in the Portland Cement Pervious Pavement Manual. Before accepting the load, be sure that it meets the desired specifications. To assure proper operation, it is crucial that (1) the total water content in the mixture be within the desired narrow range; (2) the mixture is held within the truck for no more than 45 to 60 minutes depending on air temperature; (3) the mixture is visually inspected before placement to assure that the proper water-cement paste is uniform in consistency and adequately coating the aggregate surface; (4) the mixture should be discharged from the truck as rapidly and continuously as possible, and distributed on the prepared moist subgrade as evenly as possible; (5) spreading, strike-off, and compaction should be performed as quickly as possible; (6) a vibrating screed should be used to strike-off the mixture, with an inch of material along the base of the screed to provide uniform compaction; (7) compaction, using a small plate vibrating or roller compactor on top of 3/4" plywood, should be done within 20 minutes after strike-off to minimize the potential for raveling; (8) moist curing is started within 20 minutes after placement. The concrete should be sprayed with a light mist of water so as not to wash the cement paste off the aggregate. It is then covered with plastic sheets for 3 to 7 days.

- Be sure that the adjacent areas and all of the contributing drainage area is completely stabilized to minimize the generation of sediments that can enter the pervious pavement.

- Post signs to alert users that the area has pervious pavement and that vehicles with muddy tires should not enter.

- Although snow and ice tends to melt more quickly on pervious pavement, it may still be necessary to apply deicing compounds. Do not use sand or ash because they may cause clogging of the pavement. Remember the potential for ground water pollution.

Modular Pavement



Description

Pavement consisting of strong structural materials having regularly interspersed void areas which are filled with pervious materials such as sand, gravel, or sod. Generally used in low-volume traffic areas such as the outer parts of a parking lots or in parking lots serving parks or recreational areas. Modular pavement systems vary considerably in configuration. Categories include:

1. Poured-in-place Concrete Slabs - Steel reinforced concrete slabs covering large areas are poured in place with void areas in between. Suitable for heavy loads and has maximum resistance to movement caused by frost heave or settling.
2. Precast Concrete Grids - Concrete paving units incorporating void areas. Types include *lattice pavers*, which generally are flat and grid-like in surface configurations, and *castellated pavers*, which show a higher percentage of grass surface and have a more complex surface configuration characterized by crenels and merlons that are exposed when pervious materials are added.
3. Modular Unit Pavers - Small pavers in various shapes which may be clay bricks, granite sets, cast concrete, or even pervious concrete. These pavers are monolithic units which do not have void areas but provide pervious void spaces in the gaps between them.
4. GeoWeb - A geotextile material which is installed as a framework to provide structural strength, then filled with sand, and sodded to provide a completely grassed parking area.

Pollutant Removal Mechanisms

- Percolation of rainfall and runoff through the voids into the underlying permeable base and then into the soil.
- Filtration of rainfall and runoff by the vegetation that can grow in the voids.

Advantages

- Reduces site imperviousness thereby reducing stormwater volume and peak discharge rate.
- Modular pavements reduce hydroplaning and skidding by up to 15%.
- Water puddles less on modular pavement since it moves rapidly into the underlying permeable base and soils.

Disadvantages

- The major disadvantage is the tendency for modular pavement void spaces to clog, especially if not vegetated. Proper maintenance is essential to ensure long term performance.
- Modular pavement may cost up to twice as much as conventional pavements. Some of the additional cost can be recovered by the decreased need for stormwater pipes, etc.
- Spills of gasoline or other potentially hazardous materials can lead to soil or ground water contamination. Spills must be immediately vacuumed up with possible removal and replacement of underlying soils.
- In areas with long duration rainfalls, such as the Pacific Northwest, anaerobic conditions may develop in the underlying soils since the soils are unable to dry out between storms. This can prevent aerobic bacteria from reducing organic pollutants. Additionally, the wet subgrade soils may not support the design load.
- Can present a safety hazard to some users (i.e. women in high heeled shoes.

Operation, Maintenance, and Management Needs and Obligations

■ Operation

Successful operation depends on maintaining the percolation rate of the void spaces and the underlying base and soils. Keys to assuring long term performance are accurate estimation of the soil's percolation rate, proper construction, and regular maintenance.

■ Maintenance

Activities necessary to maintain the performance of modular pavements include:

- "Good housekeeping" practices by the users to minimize the production and transport of particulates onto the modular pavement. This includes vegetative stabilization of adjacent areas which may erode and become a source of sediments.

- Replacement of base and underlying soils if they become clogged and water ponding persists.

- When turf is incorporated into the installation, normal turf maintenance, will be necessary. However, mowing is seldom required in areas of frequent traffic and fertilizers and pesticides should be used sparingly since they may adversely affect concrete products and ground water.

■ Management

All modular pavements should be inspected several times in the first few months after construction to assure that they are working correctly and were installed properly. Inspections should be conducted after storms to check for long duration surface ponding that may indicate local or widespread clogging.

Recommendations to Assure Proper Operation, Maintenance, and Performance

1. As with all infiltration practices, accurate estimation of the soil's percolation rate is essential.

2. Be sure turf block parking is appropriate for the setting and the primary users.

3. Construction recommendations:

- Install all modular pavements following manufacturer's specifications. The requirement for skilled labor for laying modular pavement may be reduced if mechanical vibrators are used for levelling uneven surfaces.

- To preclude premature clogging and/or failure, modular pavements should not be placed into service until the entire contributing surface drainage area has been completely stabilized.

- Clearly mark the planned area for modular pavement to prevent heavy equipment from compacting the underlying soils.

- Install diversions to keep runoff off the area until the modular pavement is in place.

- Excavate the subgrade soil using equipment with tracks or oversized tires to minimize compaction.

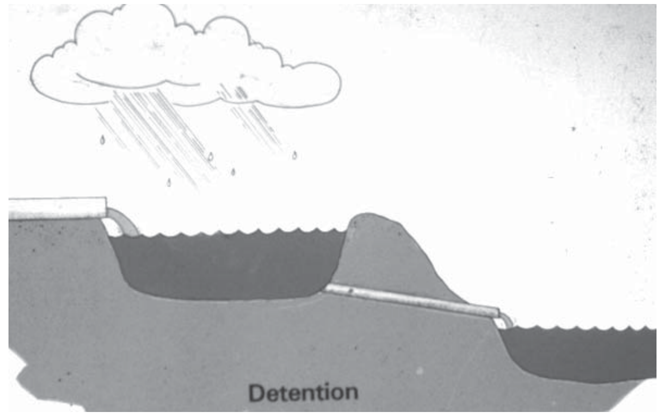
- Be sure that the adjacent areas and all of the contributing drainage area is completely stabilized to minimize the generation of sediments that can enter the modular pave ment

- Although snow and ice tends to melt more quickly on modular pavement, it may still be necessary to apply deicing compounds. Do not use sand or ash because they may cause clogging of the pavement. Remember the potential for ground water pollution.

Turf block parking lot under construction.

Geoweb fabric being installed and filled with sand before sod is added to create grass parking.

Detention Practices



Description

A family of practices which "detain" runoff, typically from a design storm, and then discharge it, usually at the pre-development peak discharge rate. Detention practices can be classified as dry detention, extended dry detention, or wet detention systems.

Purpose

Traditionally, detention practices, especially dry detention, have been used only for flood protection. They detain runoff and then discharge it at a specified rate supposedly reducing the potential for downstream flooding by delaying the arrival of runoff from upper parts of a watershed. More recently, detention system designs have been modified to also reduce stormwater pollutants. For example, dry detention systems have been modified to extend the detention time of runoff thereby increasing pollutant settling. Wet detention systems have been modified to increase residence time and flow path, and to include shallow littoral zones in which wetland plants grow.

Pollutant Removal Mechanisms

The primary "treatment" mechanism of all detention systems is settling or sedimentation. However, the pollutant removal mechanisms vary depending on the type of detention system. They will be discussed in the following BMP Fact sheets on dry detention, extended dry detention, and wet detention systems.

Expected Stormwater Quantity and Quality Performance

All detention systems are highly effective in reducing peak discharge rates. Depending on their design and their location within a watershed, they also may be effective in reducing downstream channel erosion and downstream water elevations and flooding.

Stormwater treatment effectiveness depends on the type of detention system. In general, they can be ranked, from least to most effective, in their ability to remove stormwater pollutants: dry detention, extended dry detention, wet detention. Unlike dry detention systems, wet detention provides mechanisms that promote the removal of dissolved stormwater pollutants, not just particulate pollutants.

Since each type of detention system is so different, aspects of their use, operation, maintenance, and management will be discussed separately in the following sections on dry detention, extended dry detention, and wet detention.

Dry Detention Basin

Description

An area used to detain stormwater for a relatively short period of time to reduce downstream peak discharge rates. The area should go dry between storms. This is the traditional type of detention system used in "drainage" programs for many years to help provide flood protection.

Pollutant Removal Mechanisms

Settling or sedimentation of larger, heavier particles is the primary mechanism. In some systems, limited infiltration may occur.

Advantages

Since these systems are dry between storms, the land area can be used for low intensity secondary uses such as recreation or sports.

Disadvantages

- Very poor stormwater treatment effectiveness.
- Often considered unattractive nuisances by residents.
- Poorly designed or maintained systems which do not go dry may become breeding areas for mosquitoes.

Expected Stormwater Quantity and Quality Performance

Dry detention systems generally provide good attenuation of peak discharge rates. However, their pollutant removal effectiveness generally is very low, depending on detention time, flow path, and frequency of sediment removal. Sedimentation of larger particles is the primary treatment in dry detention systems. Therefore, the small particles, to which the majority of stormwater pollutants such as metals adhere, are discharged downstream. The ranges of expected pollutant removal in dry detention systems are:

• Total Suspended Solids	20 to 60 percent	• Total lead	20 to 60 percent
• Total Phosphorus	10 to 30 percent	• Total Zinc	10 to 50 percent
• Total Nitrogen	10 to 20 percent	• Total copper	10 to 40 percent
• COD	20 to 40 percent	• Bacteria	20 to 40 percent

Limitations on Use

- Need fairly porous soils to assure that the bottom stays dry between storms.
- Not suitable in areas with high water tables or shallow depth to bedrock.
- Not suitable on fill sites or steep slopes.

Operation, Maintenance, and Management Needs and Obligations

■ Operation

Successful operation depends on maintaining the storage volume, the discharge rate, and, in many cases, the system's infiltration capability.

■ Maintenance

Activities necessary to maintain the functioning of a dry detention system include:

- Frequent removal of accumulated solids, debris, and litter from the detention area, especially from the low flow channel. Sediments should be removed when they are dry and have cracked, separating from the bottom and vegetation.

- Removal of debris from the control device, especially if it has a small orifice.

- Mowing and removal of vegetation. The use of low growing, native grasses is recommended to minimize mowing frequency and the need for irrigation and fertilizers, which should only be used when absolutely necessary.

- Vegetative stabilization of eroding sides or bottom.

■ Management Needs and Obligations

Inspect monthly and after large storms to assure proper discharge, prevention of soggy bottoms, assure healthy vegetative growth, and to monitor accumulation of sediments.

Recommendations to Assure Proper Operation, Maintenance, and Management

1. Provide a system to allow stormwater to bypass the facility. This will allow maintenance to be done faster, and during the rainy season if needed.

2. Design the dry detention system as an "off-line" facility.

3. The seasonal high water table and bedrock should be at least four feet beneath the bottom of the system to minimize the potential for ground water contamination and to assure that the bottom is dry.

4. Use a sediment forebay at all inflow points to trap sediments and allow for easy removal.

5. The length of the basin should be at least three times the width (preferably five times), with the basin narrow at the inlet and wide at the outlet.

6. Side slopes should be at least 3:1 for safety and ease of mowing, although 4:1 slopes are optimal.

6. The basin floor should be flat with a 2% slope toward the outlet.

7. Have an area on-site to hold sediments that are removed from the dry detention system. The area should be capable of holding the sediments removed during a two year period. Sizing of the disposal area should be based on the estimated annual sediment load trapped.

8. Provide dedicated access to the forebay and to all parts of the dry detention system for maintenance equipment and vehicles.

9. <u>Construction Recommendations:</u>

- If the system will rely on infiltration to some extent, then follow the recommendations for construction of infiltration practices.

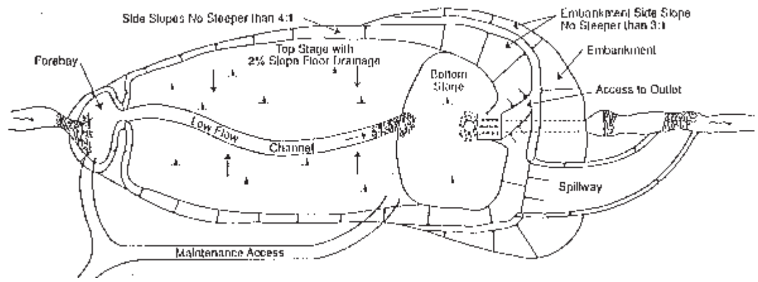
- Make sure the embankment and discharge structure are installed properly, at the correct elevations, and with proper compaction.

- Make sure that anti-seep collars are installed properly.

South Florida dry detention system integrated into the site's landscaping.

Extended Dry Detention Basin

Extended Dry Detention Schematic



Description

A dry detention system with a discharge structure which is modified to extend the detention time of runoff, typically up to 24 to 48 hours. The modified discharge may also include some type of filtering device (i.e., gravel or sand envelope) to improve the removal of particulate pollutants.

Extended dry detention systems may be designed as either on-line or off-line facilities. They also may be designed as either a single-stage or two-stage basin. Single-stage basins normally are used only for flood control and are not recommended for stormwater treatment. A two-stage basin detains runoff from small, frequent storms and the "first flush" from larger storms in a lower second stage, with a normally dry upper stage for detention of larger storms for flood control. To improve stormwater treatment the second stage can be designed and managed as a shallow marsh.

Pollutant Removal Mechanisms

- Settling or sedimentation, especially of larger, heavier particles, is the primary mechanism.
- Plant uptake and bacterial activity in two-stage systems with a shallow marsh.
- In some systems, limited infiltration may occur.

Advantages

Since many of these systems are dry between storms, the land area can be used for low intensity secondary uses such as recreation or sports.

Disadvantages

- Relatively low stormwater treatment effectiveness
- May be less reliable in treating stormwater pollutants than other BMPs
- Primarily remove particulate pollutants with little removal of dissolved pollutants.
- Shallow depth can significantly warm the detained water, making use inappropriate when discharge is to temperature sensitive receiving waters, such as a trout stream.
- Often considered unattractive nuisances by residents.
- Poorly designed or maintained systems which do not go dry may become breeding areas for mosquitoes.
- Discharge structure may clog easily, especially if a filtration system is used.
- Relatively frequent removal of accumulated sediments is needed to prevent resuspension and discharge and to maximize treatment effectiveness.

Expected Stormwater Quantity and Quality Performance

Extended dry detention systems generally provide good attenuation of peak discharge rates but do not reduce runoff volume. Pollutant removal effectiveness generally is low but can be improved by design considerations such as making the system off-line, increasing the "treatment volume", and increasing the detention time. The ranges of expected pollutant removal in extended dry detention systems are:

• Total Suspended Solids	30 to 80 percent	• Total lead	20 to 70 percent
• Total Phosphorus	15 to 40 percent	• Total Zinc	10 to 60 percent
• Total Nitrogen	10 to 40 percent	• Total copper	10 to 50 percent
• COD	20 to 50 percent	• Bacteria	20 to 60 percent

Limitations on Use

- Require fairly porous soils to assure that the bottom stays dry between storms.
- Not suitable in areas with high water tables or shallow depth to bedrock.
- Not suitable on fill sites or steep slopes.
- Requires elevation differential between inlet and outlet.
- May not be suitable if receiving water is temperature sensitive, such as a trout stream.

Operation, Maintenance, and Management Needs and Obligations

■ Operation

Successful operation depends on maintaining the storage volume, the discharge rate, and, in many cases, the system's infiltration capability.

■ Maintenance

Activities necessary to maintain the functioning of an extended dry detention system include:

- Frequent removal of accumulated solids, debris, and litter from the detention area, especially the low flow channel if included. Sediments should be removed when they are dry and have cracked, separating from the bottom and vegetation.

- Removal of debris from the control device since it typically will have a small orifice.

- Mowing and removal of vegetation. The use of low growing, native grasses is recommended to minimize mowing frequency and the need for irrigation and fertilizers, which should only be used when absolutely necessary.

- Vegetative stabilization of eroding sides or bottom.

- Management of aquatic plants if portions of the basin have been designed as a constructed wetland.

- Management Needs and Obligations

Inspect monthly and after large storms to assure proper discharge, prevention of soggy bottoms, assure healthy vegetative growth, and to monitor accumulation of sediments.

Recommendations to Assure Proper Operation, Maintenance, and Management

1. Include a system to allow stormwater to bypass the facility. This will allow maintenance to be done faster, and during the rainy season if needed.

2. Design the extended dry detention system as an "off-line" facility.

3. The seasonal high water table and bedrock should be at least four feet beneath the bottom of the system to minimize the potential for ground water contamination and to assure that the bottom stays dry.

4. Use a sediment forebay at all inflow points to trap sediments and allow for easy removal.

5. The length of the basin should be at least three times the width (preferably five times), with the basin narrow at the inlet and wide at the outlet.

6. Side slopes should be at least 3:1 for safety and ease of mowing, although 4:1 slopes are optimal.

7. The basin floor should be flat with a 2% slope toward the outlet.

8. The discharge structure should incorporate mechanisms to promote filtering of stormwater pollutants but minimize the potential for clogging. Experience in Austin (TX), Denver (CO), Washington, and Florida has found that a perforated riser pipe, wrapped in filter fabric and surrounded by gravel (1" to 3" stone), can greatly reduce the potential for orifice clogging. This design also increases the treatment effectiveness.

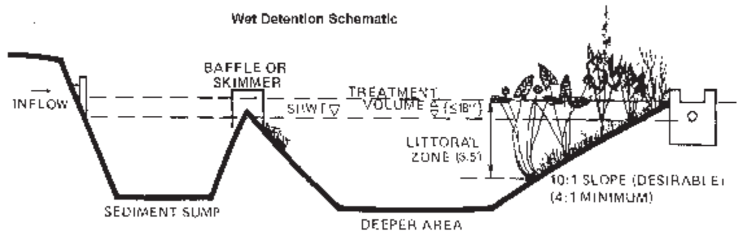
9. Have an area on-site to hold sediments that are removed. The area should be capable of holding the sediments removed during a two year period. Sizing of the disposal area should be based on the estimated annual sediment load trapped.

10. Provide dedicated access to the forebay and to all parts of the extended dry detention system for maintenance equipment and vehicles.

<u>11. Construction Recommendations:</u>

- If the system will rely on infiltration to some extent, then follow the recommendations for construction of infiltration practices.
- Make sure the embankment and discharge structure are installed properly, at the correct elevations, and with proper compaction.
- Make sure that anti-seep collars are installed properly.

Wet Detention Pond



Description

A detention system with a permanent pool of water which is completely or partially displaced by stormwater from the contributing drainage area. Water is temporarily stored before gradually discharging it, typically at the predevelopment peak discharge rate. A wet detention system is essentially a small lake with rooted wetland vegetation in the littoral zone.

Pollutant Removal Mechanisms

- Settling or sedimentation.
- Chemical flocculation which occurs when heavier sediment particles overtake and coalesce with smaller, lighter particles to form still larger particles.
- Dissolved stormwater pollutants are reduced by a variety of biological processes including filtering, adsorption onto bottom sediments, uptake by aquatic plants including algae, and metabolism by microorganisms inhabiting bottom sediments and aquatic plants.
- ***Removal of stormwater pollutants primarily occurs during the relatively long quiescent period between storms***.

Advantages

- Relatively high level of flood control and stormwater treatment.
- Can be used in areas with a high water table or poorly drained or percolating soils.
- Excellent multiuse BMP which can provide ancillary benefits such as habitat, recreational opportunities, high value aesthetics associated with "lake front" property, and serving as a source of fill dirt often needed in areas with high water tables or flat topography.
- Relatively low maintenance requirements.
- Can be used as sediment trap or basin during construction phase of a project.

Disadvantages

- May provide limited flood storage in areas with high water tables.
- Safety and aesthetic problems if the pond, especially the littoral zone and discharge structure, is not maintained properly.
- Fairly land intensive, often two to five percent of contributing area.
- Wet season may not be coincident with plant growing season.
- May be regulated as a "wetland".
- May be an attractant for children creating potential safety and liability issues.
- May become fecal and nutrient source because of attracted waterfowl.

Expected Stormwater Quantity and Quality Performance

Wet detention systems provide very good flood control and stormwater treatment benefits. Only infiltration practices provide better management of stormwater quantity and quality. The permanent pool and wetland vegetation provide for a variety of pollutant removal mechanisms which are highly effective in removing both particulate and dissolved stormwater constituents. Treatment effectiveness of wet detention systems depends on a number of design factors including the storage volume, detention time, permanent pool volume, volume ratio, depth of permanent pool, elevation of control structure in relation to seasonal high water table elevation, pond geometry, size and location of littoral zone, type and density of littoral zone plants, and use of the "BMP Treatment Train" to incorporate pretreatment devices such as sediment forebays and swale conveyances. The ranges of expected pollutant removal in wet detention systems are:

• Total Suspended Solids	50 to 90 percent	• Total lead	30 to 90 percent
• Total Phosphorus	30 to 80 percent	• Total Zinc	30 to 90 percent
• Total Nitrogen	30 to 60 percent	• Total copper	20 to 80 percent
• COD	30 to 70 percent	• Bacteria	20 to 80 percent

Limitations on Use

- Not suitable on fill sites or near steep slopes.
- May need supplemental water supply to maintain permanent pool if not dug into the ground water.
- Minimum contributing drainage area of 8 to 10 acres is needed to maintain the permanent pool.
- Infeasible in very dense urban areas or areas with high land costs.
- May not be suitable if receiving water is temperature sensitive, such as a trout stream.

Operation, Maintenance, and Management Needs and Obligations

■ Operation

Successful operation depends on good design, construction, and maintenance, especially of the discharge structure and littoral zone vegetation.

■ Maintenance

Activities necessary to maintain the functioning of wet detention system can be broken down into two categories: Routine and Corrective.

Specific routine maintenance activities include:

- Grass mowing and removal from side slopes and the embankment.
- Removal of trees, brush, and animal burrows from the embankment.
- Vegetative cover stabilization to prevent erosion of side slopes and the embankment.
- Removal and disposal of trash and debris, especially from inlet or outlet structures.

- Monitoring and periodic removal of nuisance species in the littoral zone.
- Thinning and transplanting of thriving littoral zone plants as needed to maintain good growth throughout the littoral zone.
- Monitoring for mosquitoes and introduction of *Gambusia* or other natural predators as needed.
- Monitoring of sediment accumulations in forebays or in the pond bottom.
- Monitoring of channel erosion in downstream conveyances.

Specific corrective maintenance activities include:

- Pond dewatering and removal of accumulated sediments. The frequency will depend on a variety of factors including use of pretreatment BMPs or forebays, contributing drainage area, land use, sediment loading, etc. Yousef et. al. (1992) determined that the typical wet detention system in Florida needed sediment removal every 10 to 15 years. A good rule of thumb is to remove sediments when 10 to 20% of the system's storage volume has been lost.
- Structural repairs to inlets, outlets, or discharge structure, including the emergency spillway.
- Repairs to the dam, embankment, or slopes to prevent erosion or piping.
- Repairs to fences, if applicable.

■ Management Needs and Obligations

- Inspect monthly and after large storms to assure proper discharge, monitor accumulations of trash and debris, monitor sediment accumulations in forebays or inlets, determine mowing or vegetation removal needs, and determine health of littoral zone vegetation.

- Monitor pond sediment accumulations annually. This can be done by coring, installation of a permanent measuring device such as a "yardstick", or even by mapping the pond bathymetry in larger ponds.

Recommendations to Assure Proper Operation, Maintenance, and Management

1. The design should include a bottom bleeddown device, and preferably a system that allows stormwater to bypass the facility. This will allow easy pond dewatering and facilitate maintenance.

2. Use the "BMP Treatment Train" concept such as swale conveyances and sediment forebays, especially if the wet pond is going to be promoted as an aesthetic amenity for the development.

3. To maximize removal of dissolved pollutants, pool storage hydraulic residence time should be at least 2-3 weeks. This generally means that the pond will consume 3-7 percent of the contribution drainage area depending on factors such as impervious area, rainfall characteristics, water table elevation, etc.

4. The system should include shallow areas (less than 3 feet deep) and deep areas (more than 8 feet). The shallow areas should be used for the littoral zone which provide habitat for aquatic wetland vegetation and serves as a shallow bench along the shore, helping to minimize the potential for drowning. Deep areas should make up 25-50 percent of the pond and be located near inflow points. The maximum depth should be limited to a level that minimizes the risk of thermal stratification. This helps to reduce short circuiting, maintain aerobic bottom waters and sediments, and minimize the potential for ground water contamination.

5. The littoral zone should cover at least 30% of the pond's surface area and slope gently (6:1 or flatter) to a depth two feet below the control elevation. Ideally, the littoral zone and its emergent wetland vegetation should extend around the entire perimeter of the pond with an expanded littoral zone at the outlet area. A wide variety of native plants, especially those with attractive flowers, should be used as part of the "aquascaping" of the system, helping to increase aesthetics. Unfortunately, experience has shown that many residents will remove the beneficial aquatic plants adjacent to their lots because of concerns about snakes and other "swamp critters". This has led to the practice of concentrating the littoral zone near inflows and at the outlet. A better alternative is to educate residents about the values - environmental, safety, and aesthetics - of the littoral zone plants.

6. Pond geometry has a very strong influence on the effectiveness of wet detention systems. Little or no pollutant removal occurs in dead storage areas where the inflow is bypassed without mixing. To avoid this problem, the effective length to width ratio should be at least 3:1 and preferably 5:1. Additionally, the locations of inflows and the discharge structure should minimize short circuiting and maximize the flow path.

7. Better performance can be expected by enlarging the surface area to gain volume as opposed to deepening the pond.

8. Proper design, construction, and maintenance of the discharge structure and the dam or embankment is critical, especially to minimize potential downstream damage from structural failure. In particular, the designer should:

   - Avoid potential piping of water along the outside of the outlet conduits by using drainage seepage diaphragms, or by careful material selection and good compaction around the conduit.
   - Minimize the number of conduits through the embankment.
   - Ensure against leaky joints within the embankment.
   - Not use thin-walled conduit through the embankment without a protective exterior encasement.
   - Provide a safety factor in outlet structure openings to account for debris collection. Spillway and discharge structure entrances are natural locations for debris buildup.

9. Provide access to all parts of the system for equipment needed to conduct maintenance. The maintenance right-of-way should be at least 20 feet wide, as should any fence gates.

10. Construction recommendations:

Failure to properly construct the wet detention system, especially the embankment (dam) and discharge structure, can lead to failure possibly resulting in downstream flooding, property damage, and even personal injury. Experience has shown that problems in constructing wet detention systems primarily are associated with the following:

A. Contractor error

- Construction sequence or plans are not followed.
- Concrete placement doesn't seal riser bottom.
- Pipes are improperly placed or damaged while installed.
- Separation of joints due to uneven settlement.
- Connections are not water tight.

B. Improper use of soil materials.

- Overly pervious materials are used around pipes or in the dam resulting in piping or failure.
- Top soil not spread or spread too thinly resulting in poor vegetative cover and erosion.

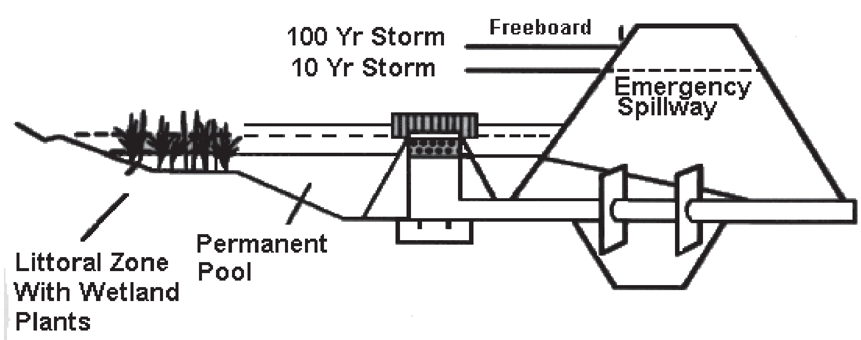
C. Principal spillway materials are not water tight.

- Connecting bands and gaskets are from different manufacturers or are too narrow.
- Improper pipe placement - uneven grades, settlement, or poor alignment.
- Water movement through connections from saturated zone.

D. Availability of specified materials.

- Rip rap sizes are unavailable.
- Materials not present when needed to insure timely construction during critical periods.

Wet Detention Schematic

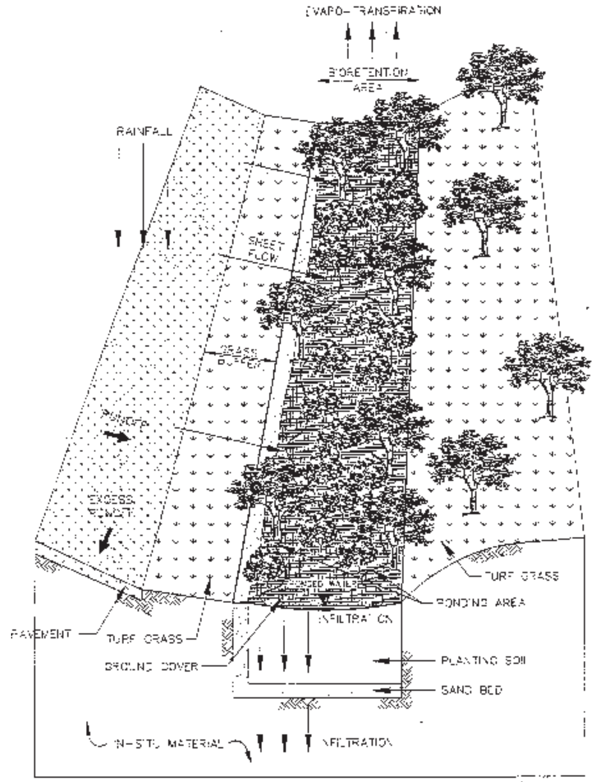


To avoid the problems described above it is important to follow the construction sequence, especially if the wet detention system is used as a sediment basin during construction. A potential construction sequence is:

1. Pre-construction meeting
   - Stress importance of proper construction sequencing and implementation.
   - Determine project phasing, especially of structures.
2. Install erosion and sediment controls.
3. Clear and grub site.
4. Strip and stock pile top soil
5. Excavate and backfill the core trench.
6. Install the principal spillway - pay special attention to compaction and installation of anti-seep devices.
7. Construct the dam and emergency spillway.
8. Excavate pond.
9. Spread top soil.
10. Vegetatively stabilize all areas.
11. If the wet detention system was used as a sediment basin, remove accumulated sediments to restore required storage volume.
12. Plant the littoral zone.

Wet detention pond at the Fl. Dept. of Environmental Protection office in Tallahassee.

Biofiltration Practices



Description

Biofiltration is a term used to describe the generally simultaneous processes of filtration, infiltration, adsorption, ion exchange, and biological uptake of pollutants from runoff as it flows through a vegetated stormwater management system. Biofiltration practices include vegetated swales, filter strips, and bioretention areas. Swales are conveyances where the flow passes through vegetation at some specified depth. Filter strips are broad surfaces which receive flow as a well distributed thin sheet. Bioretention practices capture sheet flow from impervious surfaces and treats it by infiltration, filtration, plant uptake, and microbial processes as the runoff flows through native forest or landscaped areas.

Purpose

Biofiltration practices are used primarily to reduce stormwater pollutants through natural vegetative processes, but they can also reduce stormwater volume if infiltration occurs.

Pollutant Removal Mechanisms

- Infiltration, ion exchange, and adsorption
- Settling
- Vegetative filtration and uptake
- Microbial action
- The degree to which the various pollutant removal mechanisms operate depends on soil properties, condition and types of plants, depth, water velocity, slope, and residence time.

Advantages

- Can be incorporated into a site's landscaping and open space areas.
- Very effective at reducing oil, grease, and petroleum hydrocarbons.
- Excellent use as part of the "BMP Treatment Train".
- Can be aesthetically pleasing and enhance parking areas.

Disadvantages

- Not useful by themselves for reducing stormwater quantity.
- Successful operation depends mainly on proper construction and maintenance, which requires effective inspection and enforcement efforts.
- Except for swales, the treatment effectiveness of biofiltration practices is still largely unknown.
- Too little is known about the treatment benefits of various plant species to make sound recommendations on the types of plants to use in biofiltration practices. Still, since filtering is the main function performed by the plants, the most important factor is a uniform, dense growth of fine grasses or herbaceous wetland plants.

Expected Stormwater Quantity and Quality Performance

Biofiltration practices, especially swales and filter strips, and bioretention practices generally provide minimum stormwater quantity benefits such as attenuation of peak discharge rates or runoff volume. The extent of these benefits will depend largely on how much infiltration of runoff occurs.

Stormwater pollutant removal by biofiltration systems will vary depending on a wide variety of design factors, especially the amount of infiltration and the hydraulic residence time. In general, biofiltration swales are very good at reducing particulate runoff pollutants such as total suspended solids, turbidity, and the least soluble metals such as lead, iron, and zinc. Materials which adhere to grass surfaces, such as oil and grease and total petroleum hydrocarbons are also effectively removed. Removal of nutrients, especially nitrogen, and coliforms are often inconsistent, with best removals seen for bioavailable phosphorus. Some authorities believe that biofilters can achieve better nutrient reductions if vegetation is carefully mowed and removed before it dies and releases assimilated nutrients but this hypothesis is unproven. There is little information on the pollutant removal effectiveness of filter strips or bioretention areas.

The ranges of expected pollutant removal in biofiltration swales are:

• Total Suspended Solids	50 to 85 percent	• Total lead	40 to 80 percent
• Total Phosphorus	20 to 40 percent	• Total Zinc	30 to 80 percent
• Total Nitrogen	0 to 40 percent	• Total copper	30 to 60 percent
• COD	10 to 40 percent	• Bacteria	10 to 60 percent

Limitations on Use

- Can not be used where the contributing drainage area exceeds a few acres because of the excessive surface area needed to produce sufficient residence time. The maximum drainage area depends on its specific characteristics (i.e., land use, % imperviousness, etc.).
- Should not be used for erosion and sediment control during construction nor where the post-development sediment loading will be high.
- Need fairly porous soils to promote infiltration.

- Not suitable on steep slopes or where there is shallow depth to bedrock.
- May be limited to areas where summer irrigation is feasible.
- Generally not suitable in areas with high water tables, although "wet swales" with wetland plants have worked well in Florida.

Operation, Maintenance, and Management Needs and Obligations

■ Operation

Successful operation depends on proper design, especially estimation of hydraulic residence times and infiltration rates, proper construction and regular maintenance.

■ Maintenance

Activities necessary to maintain the functioning of biofiltration practices include:

- A key O&M need of biofilters is vegetation removal to maintain adequate hydraulic functioning. Biofilter turf grass height should not exceed 6 inches nor be less than 2 inches. Excessively long grass can flatten when water flows over it, preventing sedimentation. Additionally, if not removed, decaying vegetation could release captured nutrients and other pollutants.

- Frequent removal of accumulated solids, debris, and litter. Sediments should be removed when they reach 20% of the design depth in any spot, cover or hinder the growth of vegetation, or otherwise interfere with operation. Maintenance workers should give special attention to sediment accumulation in the upper portion of swales after major storm events. Sediment and large debris should be removed from biofilters at least twice annually and more frequently, if needed.

- Vegetative stabilization of eroding sides or bottom, or of bare areas created when removing sediments. Fertilizer use should be minimized. Vegetation should be maintained and replanted early enough in the growing season so that it is well established before the rainy season or before the prime growing period ends.

- If swale blocks are used to promote infiltration or sedimentation, special attention needs to be paid to their maintenance. Sediments need to be carefully removed without damaging the swale block or its associated vegetation.

- If curb cuts are used as inflows to biofilters, sediments and vegetation growths should be removed from the curb cut when they begin to interfere with inflow.

- Roadside shoulder scraping and ditch cleaning should be based on hydraulic necessity, not simply a timed schedule. When these operations are performed, only the amount of sediment to restore hydraulic capacity should be removed. More importantly, the shoulder and swale should be revegetated immediately to minimize erosion and restore treatment effectiveness. Operations should be done in the dry season.

- Implement education programs for residents near biofiltration practices, such as residents within subdivisions with swales, to teach them about their purpose, solicit their help in maintenance, and minimize use of swales as debris or trash depositories.

■ Management Needs and Obligations

- Inspect semiannually and, when possible, after large storms to assure proper flow, vegetative growth, and to monitor accumulation of sediments, trash, and debris.

- Institutionally, a stormwater program which allows the use of biofiltration practices must have an inspection and enforcement program to assure that maintenance occurs. Public education programs also are highly recommended.

Recommendations to Assure Proper Operation, Maintenance, and Management

1. For dry systems, the seasonal high water table and bedrock should be at least four feet beneath the bottom of the system to minimize the potential for ground water contamination and to assure that the bottom is dry.

2. To provide proper flood control, biofilters must be combined with more traditional practices such as detention. Biofilters can either be designed as on-line components of a BMP Treatment Train or as an off-line stormwater treatment component of the overall stormwater management system. Off-line systems are preferable because the detention element can meter flow into the biofilter up to the design storm intended to receive treatment and protect the biofilter from high flows.

3. The design of biofilters, especially swales and filter strips, will depend largely on the rainfall, topographic, and land cover characteristics of the site. These will determine the "treatment volume" and greatly influence the location and use of biofilters, along with other design considerations such as their residence time. The specific length of a biofilter will depend largely on the residence time and the associated length and width.

4. It is essential that flow through biofilter systems be uniform sheet flow (filter strips) or flow of minimal depth below the vegetation height (swales). This will maximize contact with the vegetation and microbes which promote treatment. This requires a flat bottom to minimize any potential for channelized flow.

5. Use a flow-spreading device and/or energy dissipation device at the inlet to minimize erosion and maximize uniform distribution of flow.

6. Maximum design velocity should not exceed 1.5 to 3.0 feet per second to prevent erosion and maximize treatment capability.

7. Slopes of biofilters should be between 2 and 4 percent. Underdrains may be needed if slopes are less than 2 percent and a dry system is desired. Swale blocks should be used when slopes exceed 4 percent.

8. Water depth should be no greater than one half the height of the vegetation up to a maximum of 5 inches. Ideally, the water depth should not exceed 2 inches.

9. Biofilters should be situated along natural drainage routes and contours whenever feasible. Designers can reduce the risk of channelized flow and erosion by not forcing runoff to flow in unnatural directions.

10. Biofilter designers must investigate the climate and microclimate of the site in order to choose optimal varieties of vegetation. Grasses are the superior choice of vegetation because they are resilient, provide abundant surface area, and can sprout through thin deposits of sand and sediment. Grasses that are stiffer, denser, and have greater leaf surface areas are preferable. If water tables are high, a "wet swale" should be designed using appropriate wetland plants.

11. In regions that experience extended dry periods, selecting drought-tolerant plant species or constructing biofilters in locations where soils remain moist during dry periods can reduce irrigation needs.

12. Avoid heavy and prolonged shading of biofilters by adjusting placement relative to buildings and trees.

13. Construction recommendations.

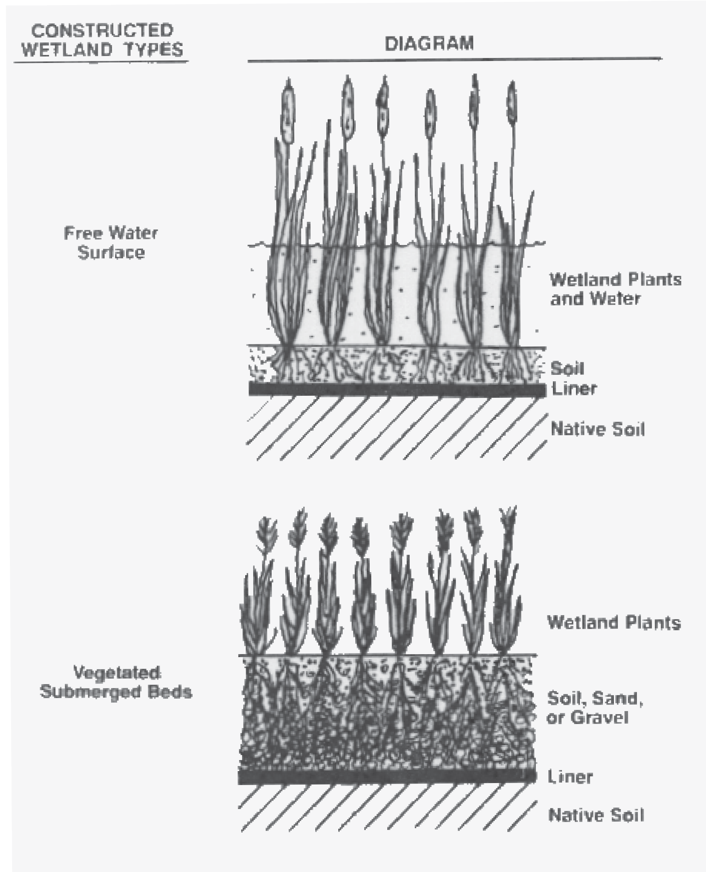
- Since most biofilters rely upon infiltration, follow construction recommendations for "Infiltration practices". The key is to minimize compaction of the soil and the resulting reduction of the infiltration rate of the soil.

- Do not place biofilters into operation until the contributing drainage area is completely stabilized.

- If possible, divert runoff during the period of vegetation establishment. If this is not possible, sodding should be used whenever possible, especially if significant runoff could occur before vegetation establishment. Other methods of minimizing erosion in flowing channels includes the use of "erosion mats" combined with seed.

Erosion matting is used to prevent erosion of biofiltration swale during establishment of its vegetative cover.

Constructed Wetlands



Description

A runoff storage and treatment area constructed in uplands which is vegetated with aquatic macrophyte plants native to the area. These systems attempt to incorporate properties of natural wetlands such as shallow, sheet flow through dense, diverse assemblage of wetland plants which also serve as habitat for microorganisms. There are numerous configurations for constructed wetlands. They range from shallow marshes, to the littoral zones of wet detention systems, to a combination extended detention and marsh system.

Purpose

Constructed wetlands are being used to remove stormwater pollutants through the natural processes that occur within these ecosystems.

Pollutant Removal Mechanisms

- Settling or sedimentation.
- Adsorption to sediments, vegetation, or detritus
- Filtration by plants.
- Microbial uptake and/or transformations.
- Uptake by wetland plants or algae.
- Extended detention.
- ***Removal of stormwater pollutants primarily occurs during the relatively long quiescent period between storms***.

Advantages

- Can be used in areas with high water table or poorly drained or percolating soils.
- Can be used in areas with highly pervious soils if a liner is used to minimize infiltration.
- Can remove dissolved pollutants.
- Can be aesthetically pleasing and provide wildlife habitat.

Disadvantages

- In many parts of the country, especially in the western states, wetland vegetation is dormant during the rainy season. However, since plant uptake is only a minor mechanism in removal of most pollutants, a standing crop of vegetation can still provide filtration and an area for surface removal processes.
- Provide limited flood storage and attenuation.
- Shallow depth may significantly warm the detained water, making use inappropriate when discharge is to temperature sensitive receiving waters, such as a trout stream. However, monitoring in Delaware shows that shallow, well vegetated systems have water temperatures much lower than unvegetated systems.
- Fairly land intensive.
- Possible mosquito problems associated with dense, emergent wetland vegetation.
- May be regulated as a "wetland" unless continuously operated and maintained as a treatment system.
- Can become either a nutrient or fecal "source", depending on wildlife use and populations and vegetation management.

Expected Stormwater Quantity and Quality Performance

Constructed wetlands are used primarily to remove pollutants from runoff and typically are not used by themselves to attenuate stormwater peak discharge rates or volumes. Constructed wetlands should still be considered an experimental stormwater treatment BMP as too little is known about their long-term treatment effectiveness or maintenance requirements. They have been used in numerous locations around the country with varying success. Treatment effectiveness will depend on a number of design considerations including the treatment volume, surface area to volume ratio, length and type of flow path, plant types and densities, plant growing season in relation to rainy season, deep water pools, and use of the BMP Treatment Train by incorporating pretreatment devices such as sediment forebays and swale conveyances. The ranges of expected pollutant removal of constructed wetland systems are (median values for the relatively soluble pollutants like phosphorus, nitrogen, copper, and zinc are likely to be in the lower part of these ranges) :

•Total Suspended Solids	60 to 90 percent	•Total lead	50 to 90 percent
•Total Phosphorus	30 to 85 percent	•Total Zinc	30 to 90 percent
•Total Nitrogen	30 to 80 percent	•Total copper	20 to 80 percent
•COD	10 to 50 percent	•Bacteria	20 to 80 percent

Limitations on Use

- Not suitable on fill sites or near steep slopes.
- May need supplemental water supply to maintain base flow if not dug into the ground water.
- Unless excavated into the water table, the minimum contributing drainage area needed to maintain base flow will need to be determined. This will vary depending on rainfall and watershed characteristics.
- Overgrowth of aquatic plants can lead to reduced hydraulic capacity.
- Infeasible in very dense urban areas or areas with high land costs.

Operation, Maintenance, and Management Needs and Obligations

- Operation

Successful operation depends on good design, construction, and maintenance, especially of the sediment forebays, wetland vegetation, and the discharge structure.

- Maintenance

Activities necessary to maintain the long term functioning of a constructed wetland system are still relatively unknown. As a minimum, the following actions will be needed:

- Grass mowing and removal from side slopes and the embankment.
- Removal of trees, brush, and animal burrows from the embankment.
- Vegetative cover stabilization to prevent erosion of side slopes and the embankment.
- Removal and disposal of trash and debris, especially from inlet or outlet structures.
- Monitoring and periodic removal of nuisance plant and animal species as specified in a written procedure prepared by a wetland scientist.
- Thinning and transplanting of thriving wetland plants as needed to maintain good growth throughout the constructed wetland. Again, this should be done in accordance with a written procedure prepared by a wetland plant scientist.
- Monitoring for mosquitoes and introduction of *Gambusia* or other natural predators as needed.
- Monitoring and removal of sediment accumulations in forebays or within the constructed wetland.

- Management Needs and Obligations

- Inspect quarterly and after large storms to assure proper discharge, monitor accumulations of trash and debris, monitor sediment accumulations in forebays or inlets, determine mowing or vegetation removal needs, and determine health of wetland vegetation.
- Closely monitor the wetland plant community, both during the growing season and, if needed, during the dry season, to assure healthy growth of desired plants. Remove exotic or nuisance species as soon as they appear to limit their establishment and areal extent. Thin or transplant plants from areas where they are growing densely and use them to further establishment or growth in areas with less vigorous plant growth.

- Monitor sediment accumulations in forebays semiannually. Sediments should be removed when 25% of the storage volume of the forebay has been lost.

Recommendations to Assure Proper Operation, Maintenance, and Management

1. The design should include a bottom bleeddown device, and preferably a system that allows stormwater to bypass the facility. This will allow easy dewatering of the wetland and facilitate maintenance.

2. Use the "BMP Treatment Train" concept such as swale conveyances and sediment forebays to minimize sedimentation in the wetland. There are several rules of thumb for sizing and designing the sediment forebay. These should be reviewed and those which are relevant to the conditions at the site should be followed. For example, Delaware's stormwater program requires the forebay to be sized to hold 10% of the total basin volume with a maximum depth of four feet.

3. Follow locally applicable design guidelines which take into account local rainfall conditions, hydrology, and plant characteristics. Specific design guidelines for constructed stormwater wetlands have been developed by several state stormwater management programs including Maryland, Delaware, Florida, California, and Puget Sound. These design guidelines can be used as a starting point for the development of state, regional, or locally specific guidelines. It is important to keep the design simple and buildable without extensive supervision. Since the highest level of functioning for stormwater management requires some degree of structural complexity, however, designers and botanists should plan to be in the field to interpret the plans for construction staff.

4. Minimize short circuiting by maximizing the distance from the inlet to the outlet with a minimum length to width ratio of 3:1, preferably 5:1. Baffles, islands, and peninsulas can be used to increase the flow path.

5. The designer needs a good understanding of the local hydrology at the site proposed for a constructed wetland. The ground water table should be at or near the surface, or soil of low permeability should underlay the site. If excessive seepage is a concern, impervious liners can be used. Liners can be geotextiles or 4 to 6 inches of silt loam, clay loam, or organic muck. Experience has shown that most soils in Hydrologic Soil Groups B, C, and D will eventually seal themselves.

6. Soils must be suitable for wetland plant growth and for adsorption, especially if high removal levels of phosphorus or many metals are desired. Neutral soil pH (6 to 8) is best for supporting microorganisms, insects, and other aquatic animals, and is also best for sequestering pollutants in the sediments. Soils with fairly high levels of aluminum or iron are best for adsorption. Medium to fine textured soils, such as loams and silt loams, are optimal for establishing plants and capturing pollutants. A relatively high content of highly decomposed organics ("muck") is favorable for plant and microorganism growth and the adsorption of metals and other organic pollutants.

7. Selection of the plants needs to be done by a wetland scientist. The selection will be

based on climate, hydroperiod of the wetland, sensitivity to pollution, and aesthetic appeal. A well planned wetland will include a diverse mixture of floating, emergent, and submergent plants. The following guidelines for selection of wetland plants are offered:

- Base selections more on the prospects for successful establishment than on specific pollutant uptake capabilities. Plant uptake is a significant mechanism only for nutrients, which may be released upon the plants' death. Chemical and microbial processes remove more nutrients than plant uptake.

- Match the environmental requirements of plant selections to the conditions to be offered by the site. Consider especially the hydroperiod, light requirements, climate, sensitivity to probable pollutants, and aesthetic appeal. Also consider effects from wind, waves, and water currents.

- Select species that are adapted to the broadest possible ranges of depth, frequency, and duration of inundation (hydroperiod). Careful selection is especially important when runoff quantity control is an objective because water depths will be periodically greater than those that normally occur in natural wetlands.

- Select native species to ease establishment and minimize maintenance. Include some plants that are strong colonizers but avoid exotic species and those native species that are aggressive invaders which crowd out more desirable species.

- Use a minimal number of species for each depth zone. Diversification will occur naturally. One planting recommendations is to use three species per depth zone.

- Select mostly perennial species.

- The establishment of herbaceous plants should precede that of woody species.

- Give priority to species that have been used successfully in constructed wetlands in the past and to species that are commercially available. Use of plants propagated at wetland plant nurseries will minimize pressure to remove plants from natural wetlands.

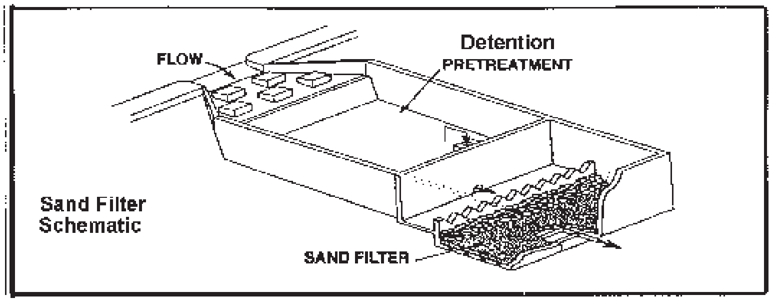
7. Experience has shown that wetland plants typically will establish themselves naturally in shallow wet ponds, regardless of soil conditions. However, it has become increasingly clear that plant communities develop best when soils harbor substantial vegetative roots, rhizomes, and seed banks. Hydric soils containing vegetative plant material are known as "wetland mulch." Use of this mulch greatly enhances plant community diversity and speeds establishment. However, the content of the mulch is unpredictable and donor sites are limited. A risk of using wetland mulch is the possible presence of exotic, opportunistic species that will displace more desirable natives. Therefore, use of mulch likely to harbor such species should be avoided. Potential sources of wetland soils include (a) spoils from maintenance of highway ditches, swales, and stormwater ponds; (b) spoils from dredging; and, (c) soils removed from natural wetlands that are going to be filled under permit (although these soils are best used for mitigating the loss). It is recommended that the upper 6 inches of donor soils be obtained at the end of the growing season, if possible.

8. While wetland plants will establish themselves naturally in shallow wet ponds, experience has shown that constructed wetlands are best established by planting. This helps to minimize colonization by undesirable invader species. It is recommended that at least half of the marsh area be planted at a constant density. The design guidelines for constructed wetlands prepared by the state stormwater programs listed above can provide a general introduction to planting densities and strategies. Planting of wetland vegetation in stormwater systems, whether a constructed wetland or the littoral zone of a wet detention system, can provide an excellent public education opportunity, especially for school children.

9. Construction recommendations

- Involve a wetland plant specialist in the system's design and construction.
- Implement good erosion and sediment controls to minimize sediment loading delivered to the constructed wetland. If necessary, divert flows to a sediment basin or other stormwater system during the construction phase until the contributing drainage area is stabilized.
- Schedule construction so that wetland plants can be planted during the growing season, preferably the beginning of it.
- The landscaping plan should be finalized after the wetland has been constructed to confirm soil, moisture, and inundation conditions.
- Order wetland plants from the nursery three to six months before the time planned for installation to ensure they will be available.
- Install control structures and embankment following wet detention guidelines.
- Grade the wetland to an interim elevation slightly deeper than desired final elevation.
- Add a 3 to 6 inch layer of soil amendments or wetland mulch, and spread out over the entire wetland area.
- Stabilize side slopes and allow the wetland to fill until the desired planting time.
- Once wetland plants are delivered to the site, be sure that they are frequently watered and well-shaded to minimize plant loss.
- If necessary, drain the wetland to a depth that facilitates planting (3 to 12 inches).
- Remove plants from their containers and loosen up their root/soil ball before planting.
- A supplemental planting should be scheduled, typically at the beginning of the second growing season, to reinforce plant establishment and obtain the desired plant coverage and density.

Stormwater Filters



Description

A family of stormwater treatment practices which typically consist of a storage BMP in conjunction with a filtering device. The most common filter media is sand, but filters have been made of peat/sand mixtures and even from leaf compost. Filters can be categorized as either "unconfined" or "confined" systems. A side bank underdrain filter within a wet detention system is an example of an unconfined filter - the sand/gravel filter media and underdrain pipes are built into the side banks of the wet pond. Alternatively, the filter media in a confined filter is contained within some type of structure, often a concrete vault. Examples include vertical volume recovery filters, the Austin sand filter, and the Delaware sand filter.

Purpose

Stormwater filters are used solely to remove certain pollutants, primarily particulates, from runoff. They must be used in combination with other BMPs to provide flood protection.

Pollutant Removal Mechanisms

- Settling or sedimentation.
- Filtration by sand or other filter media.
- Microbial uptake and/or transformations.

Advantages

- Can be used in urban areas and on highly impervious sites.
- Can be used at sites with high water tables but which have too small of a contributing drainage area for use of wet detention systems.
- May be very cost effective, especially the Delaware sand filter design where the concrete boxes are now being prefabricated in sections.

Disadvantages

- Very maintenance intensive. Filter media may need cleaning or even replacement several times a year, although this depends on a number of factors. However, this level of maintenance can be reduced by controlling erosion and otherwise restricting sediment loadings.
- Provide limited flood storage and attenuation.

Expected Stormwater Quantity and Quality Performance

Stormwater filter systems are used primarily to remove particulate pollutants from runoff and typically are not used by themselves to attenuate stormwater peak discharge rates or volumes. Treatment effectiveness will depend on a number of design considerations including the treatment volume, whether the system is on-line or off-line, whether it is a confined or unconfined filter, the type of land use, and whether pretreatment is provided by use of the BMP Treatment Train. Studies of the effectiveness of stormwater filter systems have varied greatly. In a study of a wet detention pond with an unconfined side bank filter, Harper and Herr (1993) concluded that most of the treatment occurred in the wet pond, with the filter enhancing removal of only total nitrogen, TSS, and total zinc. Field research in Austin, Texas (Chang et.al., 1990) indicates that their sedimentation/filtration systems remove 70 to 90% of the suspended solids, but only 20 to 85% of the metals, 20 to 40% of the nitrogen, and 50 to 65% of the phosphorus. Two recent studies of the Delaware sand filter design (Horner, 1995 and Bell, 1996) found these designs to be effective and fairly easy to maintain, at least for filter systems. These filters removed 80 to 90% of the total suspended solids, 40 to 60% of the total nitrogen, 40 to 75% of the total phosphorus, and 30 to 90% of the total zinc. The ranges of expected pollutant removal of stormwater filter systems are:

• Total Suspended Solids	60 to 85 percent	• Total lead	50 to 80 percent
• Total Phosphorus	30 to 75 percent	• Total Zinc	30 to 80 percent
• Total Nitrogen	30 to 60 percent	• Total copper	30 to 60 percent
• COD	30 to 75 percent	• Bacteria	40 to 80 percent

Limitations on Use

- Not suitable on fill sites or near steep slopes.
- Only use at sites with a full time maintenance entity.

Operation, Maintenance, and Management Needs and Obligations

■ Operation

Successful operation depends on good design, construction, and most importantly, on regular maintenance, especially of the filter media. With stormwater filters, the question is not whether the filter will clog, but when.

■ Maintenance

Activities necessary to maintain the long term functioning of stormwater filtrations systems include:

- Grass mowing and removal from side slopes and the embankment.
- Removal of trees, brush, and animal burrows from the embankment.
- Vegetative cover stabilization to prevent erosion of side slopes and the embankment.

- Removal and disposal of trash and debris, especially from inlet or outlet structures.
- Removal of sediments and other materials that accumulate in pretreatment practices, such as sediment traps or forebays.
- Periodic scraping and aeration of the filter media, with partial removal.
- Complete replacement of the filter media.

■ Management Needs and Obligations

- Inspect monthly and after large storms to assure proper discharge, monitor accumulations of trash and debris, monitor sediment accumulations in forebays or inlets, determine mowing or vegetation removal needs, and determine whether the filter media is clogging.
- Closely monitor clogging of the filter media to determine when maintenance is needed. There are two approaches to filter media maintenance. Most of the stormwater programs which have created design criteria for filters require eighteen inches to two feet of filter media. This allows the filter to be periodically scraped to remove an inch or two of filter media until only one foot is left. The coloration of the sand will provide a good indication of what depth of removal is required. Then additional filter media is added to restore the original two feet of filter material. Alternatively, especially for unconfined filters, the filter media is completely replaced when the time required to recover the stormwater treatment volume decreases to one-half of the design time.
- Monitor sediment accumulations in sediment traps or forebays semiannually. Sediments should be removed when 25% of the storage volume has been lost.
- Since filters often are used on highly impervious sites with potentially high loading of heavy metals and petroleum hydrocarbons, it is recommended that the filter media be analyzed periodically. This can help to prevent the accumulation of these materials in concentrations that may cause the filter media to be considered a hazardous waste. For example, Horner and Horner (1995) reported that within seven months of use, the levels of total petroleum hydrocarbons in a Delaware Sand Filter at a Seattle barge terminal exceeded Washington's Model Toxics Control Act hazardous waste threshold of 200 mg/kg by two orders of magnitude.

Recommendations to Assure Proper Operation, Maintenance, and Management

1. Use the "BMP Treatment Train" concept such as swale conveyances and sediment forebays to minimize sedimentation loadings and reduce oils, greases, and other petroleum hydrocarbons. There are several rules of thumb for sizing and designing the sediment forebay or the presettling basin/chamber for the Delaware Sand Filter (DSF). These should be reviewed and those which are relevant to the conditions at the site should be followed. For example, Alexandria's (VA) program recommends that the presettling basin/

chamber for the DSF on highly impervious sites contain a minimum of 20% of the stormwater treatment volume but that the entire volume be contained by this chamber on sites with pervious surfaces.

2. Use confined filters which are constructed as "off-line" stormwater treatment systems and which are designed to let stormwater bypass the filter during maintenance.

3. Carefully select the filter media to assure that it meets the specifications established by the stormwater program. Neutral soil pH (6 to 8) is best for supporting microorganisms and is also best for sequestering pollutants in the sediments. Soils with fairly high levels of aluminum or iron are best for adsorption and will help to increase removal of phosphorus and some metals.

4. Balance the hydrologic efficiency of the filter media with its pollutant removal effectiveness. While coarse sands will pass stormwater quickly, few pollutants are removed.

5. Unconfined, mound filters which are sodded provide a relatively low maintenance filter system and provide higher levels of treatment than do sand filters without vegetation.

6. <u>Construction recommendations:</u>

- For confined filters, do not allow inflow of runoff until construction on site is completed and all soil surfaces in the contributing drainage area are completely stabilized with vegetation.

- If detention ponds with unconfined sidebank filters are used for erosion and sediment control, the filter media should be completely replaced once construction is completed and all soil surfaces in the contributing drainage area are completely stabilized with vegetation.

- Side bank filters should contain clean out ports, spaced every 50 feet, to allow underdrain pipes to be cleaned.

- Filter media should be checked to assure that it meets all specifications, especially grain size and uniformity coefficient.

- Filter underdrain pipes should be carefully placed on a bed of gravel which has been compacted properly, thereby reducing the potential for soil piping and settling problems. Pipes must have proper slope as specified in the design plans.

- For the Delaware Sand Filter design, it is essential that:

  - The top of the sand filter is completely level.
  - The inverts of the notches, orifices, or weirs dividing the sedimentation chamber from the filter chamber are completely level.
  - If precast concrete lids are used, lifting rings or threaded sockets must be provided to allow easy removal with lifting equipment which must be readily available to maintenance crews.
  - Where underdrains are used, the minimum slope of the pipe needs to be 0.5%.

Delaware sand filter being installed in Alexandria, Virginia.

Chapter 3

Planning and Design Considerations

> **design** \di-zine\ vb 1: to conceive and plan out in the mind 2: to devise for a specific function or end 3: to conceive and draw the plans for
> - Merriam-Webster Dictionary

1. OVERVIEW

The above definition of the word "design" succinctly describes both the scope and sequence of activities typically undertaken by the designer of a stormwater management facility. Having identified a stormwater problem or need that can best be solved through the construction of a facility, the designer will then select the most appropriate type, conceptualize its function and operation, and determine the specific characteristics necessary for the facility or practice to achieve its desired performance. Having completed this, the designer must then transform these characteristics into a physical entity. This is done through the development of detailed construction plans and specifications, which are used to construct the facility in the field.

Throughout the entire endeavor, the stormwater system designer must, of course, fulfill certain technical responsibilities if the system is to comply with the standards and requirements of the community's overall stormwater management program. To do so, the designer must be familiar with these program requirements as well as the technical data, equations, and analytic techniques commonly used to meet them. However, if stormwater management is to grow beyond its traditional concerns for stormwater quantity to also address stormwater quality and nonpoint source (NPS) pollution, such technical compliance is not enough.

Instead, ***the designer must also recognize his or her unique responsibilities to the people who will inspect and maintain the facility once construction is completed***. For it is through such recognition that the designer can help ensure both the overall success of the community's stormwater management program and the quality of life of the people that will live, work, or travel past the facility they are creating. It is only by fulfilling these larger design responsibilities that stormwater management will be able to achieve and sustain the public support and participation it needs to effectively address the complex problems demanded of it. ***A description of each of these design responsibilities is presented below, with particular emphasis on minimizing and facilitating stormwater management facility maintenance***. Suggestions for meeting these responsibilities are also presented, including specific recommendations and design guidelines for various types of stormwater management practices.

1.1. Objectives

To advance the handbook's overall goal of effective and efficient stormwater management system operation, maintenance, and management, the objectives of this Chapter will be:

- To describe maintenance needs and common maintenance problems of various types of stormwater management practices, facilities, and systems.

- To demonstrate the direct link between many of these needs and problems and the decisions and actions of facility planners and designers.

- To emphasize the ability of comprehensive and enlightened planning, design, and review practices to minimize and facilitate stormwater management facility maintenance.

- To illustrate the long-term cost-effectiveness of such practices during a facility's planning, design, and review stages.

- To encourage facility planners, designers, and reviewers to regard facility maintenance as equal in importance to a proposed facility's hydrologic, hydraulic, structural, biologic, and aesthetic aspects.

- To present planning and design guidelines for specific types of stormwater management facilities and practices that minimize and facilitate post-construction maintenance.

1.2. Intended Readers

This chapter is intended primarily for the following readers:

- **Stormwater management facility planners and designers.**

- **Project design and permit application reviewers and supervisors.**

In addition, stormwater management facility owners (both present and future) can gain valuable insight into the planning and design process. This can help in the selection of a competent designer of a proposed facility and in the development of an adequate project design budget. Finally, construction managers, inspectors, and contractors can develop a greater appreciation of the overall planning and design effort and the need to follow the resulting design plans and specifications as closely as possible. Such understanding can also promote a greater exchange of information and ideas between designers and constructors, thereby enhancing the activities of both.

2. STORMWATER MANAGEMENT PRACTICES AND COMPONENTS

As noted in Chapter 2, the field of stormwater management has grown considerably in the last two decades. One of the less fortunate products of this growth has been a long and sometimes conflicting list of names for the facilities (systems) and practices produced by planners and designers. Therefore, to minimize confusion, increase effectiveness, and illustrate their different maintenance problems and needs, the following definitions have been adopted for use in this Chapter and throughout the entire handbook:

2.1. Detention Practice:

A stormwater management facility that temporarily impounds runoff and discharges it through an outlet structure. Any additional outflow through infiltration or evaporation is negligible and, therefore, not ordinarily considered in the detention system's design. Detention facilities may vary by the duration of time that they store runoff and, therefore, are further subdivided into the following three subcategories:

A. Dry Detention Facilities detain runoff for a relatively short time (e.g., 2 to 6 hours) and, as such, are normally used for erosion and/or flood control purposes. In addition, all detained runoff is released following the storm event and the facility is normally dry during inter-storm periods.

B. Extended Dry Detention Facilities detain runoff for much longer time periods (e.g., 18 to 48 hours) than dry detention facilities and, as such, also provide runoff quality benefits. Similar to dry detention facilities, they release all detained runoff through an outlet structure and are expected to be dry during inter-storm periods.

C. Wet Detention Facilities also release runoff through an outlet structure. However, some runoff is retained permanently in a pool, pond, or lake during inter-storm periods. This permanent pool provides greater water quality benefits through increased sedimentation, flocculation, and biological activity.

2.2. Infiltration Practice:
A stormwater management system that temporarily impounds runoff and discharges it through infiltration through the surrounding soil. Additional discharge may occur through evapotranspiration. Similar to dry and extended dry detention facilities, an infiltration facility is expected to completely drain and be dry during inter-storm periods. Typical infiltration practices includes infiltration basins, swales, drywells, and seepage pits.

2.3. Filtration Practice:
A stormwater management system that filters runoff through selected inorganic or relatively inert media to remove pollutants. Since filtration practices do not normally provide runoff quantity benefits, they are often used in combination with detention systems as pretreatment facilities. Typical filter media include sand, compost, gravel and other materials.

2.4. Biofiltration Practice:
A stormwater management practice that filters runoff through dense vegetation or other organic, biologically active media to remove pollutants. The organic nature of the underlying soils also promotes further pollutant removal as well as infiltration of runoff. Typical biofiltration practices include vegetated swales, filter strips, and buffer areas.

To further organize the presentation and provide thorough coverage of all facility types, each facility or practice has been broken into one or more of the components described in Table 3-1. Due to their different physical or operating characteristics, it is important to note that some practices will not have all of the components listed in the table. Additional information and photographs of the various types of stormwater management practices are presented in Chapter 2.

3. THE RESPONSIBILITIES OF THE FACILITY DESIGNER

As noted above, there are several levels of responsibility that the designer of a stormwater management facility must fulfill. ***First and foremost, the designer is responsible for complying with the technical requirements and standards of the overall stormwater management program*** of which the facility will be a part. This will typically include achieving the required level and range of peak outflow control necessary to prevent or reduce downstream flooding, as well as the detention times and pollutant load reductions necessary for stormwater quality enhancement. Additional technical requirements of the stormwater management program may include emergency discharge capacity to insure dam or embankment safety and structural and geotechnical standards to achieve stability and strength. Therefore, ***the facility designer must be familiar with the specific technical requirements of the stormwater management program as well as the theoretical basis for and use of the various hydrologic, hydraulic, structural, chemical, bio-***

TABLE 3 - 1.

Major Components of Stormwater Management Practices

COMPONENT	DESCRIPTION
PRINCIPAL OUTLET	Hydraulic structure that controls and conveys the facility's outflow to the downstream conveyance or receiving water.
EMERGENCY OUTLET	Hydraulic structure or spillway that safely conveys emergency overflows from the facility. Includes approach and exit channels.
DAM/EMBANKMENT	Wall or structural fill that impounds runoff in the facility above the adjacent ground surface.
BOTTOM	The lowest or deepest surface within the facility.
SIDE SLOPES	Slopes at dams, embankments, spillways, and facility perimeters constructed through excavation or filling.
TRASH RACK	Device placed upstream of the principal outlet or drain to intercept trash and debris that would otherwise block it.
LOW FLOW SYSTEM	Surface and/or subsurface measures that convey low and dry weather inflows to the principal outlet without storage.
INLETS	Upstream surface and/or subsurface conveyance measures that discharge runoff into the facility.
OUTFLOW SYSTEMS	Downstream surface and/or subsurface conveyances or water bodies which receive facility outflows from the principal outlet.
PERIMETER	Area immediately adjacent to the facility.
ACCESS SYSTEMS	Measures and devices that provide maintenance personnel and equipment access to various facility components.
VEGETATIVE COVER	Vegetation planted on various facility components to stabilize their surface and/or provide stormwater treatment.

logical, and geotechnical analyses typically used to comply with them.

However, the responsible facility designer (and the government reviewer approving the design) should not only be familiar with the stormwater management program's technical requirements, but also understand it's overall intent or goals. ***The responsible designer and reviewer must recognize that the program's technical requirements are only the means by which the program's goals are achieved***. As such, a stormwater management facility will contribute more towards those goals if its designer understands, for example, not just what detention time an extended detention basin should have, but why it should even have one, why it should be a certain duration, and what will happen if it doesn't. Such understanding by designers and reviewers also produces facility designs that are better able to achieve satisfactory results over a much wider range of real world conditions than the limited few used in most design processes.

In addition, due to the inherent complexities of stormwater quality and NPS pollution, the technical requirements of many stormwater management programs are not defined as precisely as the program's goals. For example, it is much easier to specify a program goal of 80 percent removal of suspended solids from stormwater runoff than it is to specify the exact technical measures required to achieve it. However, this disparity between a stormwater program's means and ends can be overcome to a great degree by the responsible designer who, aware of the disparity, is willing and able to look behind and beyond the program's somewhat more limited technical requirements and produce designs that do a better job of achieving the program's goals.

Another design responsibility is based upon the realization that the designer's efforts will ultimately result in an actual physical facility that must first be constructed and then maintained. As such, ***it is vital that the facility be both simple and practical to build and maintain***. With regards to maintenance, a study of 51 stormwater management facilities in New Jersey by the state's Department of Environmental Protection found that ***more than half of the problems encountered by maintenance personnel at the facilities could be linked to shortcomings in the planning, design, and review process***. These included:

- a lack of adequate planning and design standards,
- inadequate investigation and analysis of site conditions,
- poor understanding of facility function and operational needs,
- inattentive review, and,
- at times, simply a failure by the designer and reviewer to recognize or remember the facility's post-construction maintenance needs.

According to the study, these shortcomings and failures sometimes resulted in facility maintenance problems that "were virtually unsolvable without massive infusions of time, money, and hard work".

Flat bottom in dry detention basin prevents complete emptying and complicates basin maintenance.

Typical stormwater system operation, maintenance, and management problems that can be directly linked to poor planning and design or to inattentive review include:

MAINTENANCE PROBLEM: Soggy, unstable bottom in dry detention basin which is difficult to mow.
CAUSE: Bottom will not drain and dry completely between rain events.
SOURCE OF PROBLEM: Flat basin bottom specified by designer.

MAINTENANCE PROBLEM: Mosquito breeding in an infiltration basin.
CAUSE: Persistent standing water in bottom.
SOURCE OF PROBLEM: Basin bottom set below groundwater table due to designer oversight.

MAINTENANCE PROBLEM: Inability to drain and desilt wet detention basin.
CAUSE: Lack of low level drain.
SOURCE OF PROBLEM: Low level drain not provided due to designer oversight.

MAINTENANCE PROBLEM: Grass mowing along basin side slopes is time consuming and dangerous.
CAUSE: Excessively steep basin side slopes.
SOURCE OF PROBLEM: Excessive side slope specified by designer.

Highly visible and accessible facilities can be quickly inspected for mosquitoes and other maintenance problems.

MAINTENANCE PROBLEM: Sediment and debris removal from sand filter is time consuming and difficult.
CAUSE: Lack of access manhole from ground surface to sediment chamber.
SOURCE OF PROBLEM: Access manhole not provided due to designer oversight.

MAINTENANCE PROBLEM: Check for standing water in dry detention basin by mosquito control inspector is time consuming.
CAUSE: Basin cannot be viewed from roadway or parking lot. Inspector must stop and exit vehicle and walk to basin to view.
SOURCE OF PROBLEM: Basin located in remote part of site by designer. Access road not provided due to designer oversight.

Less durable outlet structure materials, such as cinder blocks, may save one-time construction costs but will increase long-term maintenance costs.

MAINTENANCE PROBLEM: Continuing repairs of outlet structure and trash racks required at detention basin.
CAUSE: Structural failures due to debris loadings and weather conditions.
SOURCE OF PROBLEM: Inferior, nondurable materials specified by designer.

As described above, ***poor facility design and/or inattentive review can adversely effect facility maintenance in several ways. These include hindering inspection and maintenance activities through lack of***

adequate access, increasing maintenance efforts through adverse site conditions, and creating additional maintenance needs through the use of inadequate materials. The result of any of these causes is increased maintenance time, effort, and expense and the increased potential for maintenance neglect and facility malfunction or even failure. These points have even greater impact when it is remembered that, unlike facility design or construction, which are normally completed in a matter of weeks, maintenance must be performed for the life of the facility. In addition, the increased potential for maintenance neglect and failure, which the designer or reviewer could have prevented with a few extra hours of effort in the office, may remain a threat for years to come.

It must also be noted that maintenance personnel are not the only people who will suffer the long term effects of poor facility planning, design, and/or review. As noted above, a facility design that first exists only on paper will ultimately exist in or on the ground. Since virtually all stormwater management systems are constructed as part of land development activities, other structures such as homes, offices, stores, factories, warehouses and/or roads will normally be close by, along with the people that will live, work, or travel them. ***While the facility will only be required, on average, to function a few days a month or year, these people must coexist with it every day. If the system is poorly maintained, these people may then be subjected to health threats from mosquitoes, rodents, and other vermin as well as adverse quality-of-life effects from odors or unsightly appearance***. If these conditions are due, even in part, to deficiencies in the system's design (as demonstrated above), then the planner, designer, and reviewer must share the blame for their creation.

Finally, in the design of any stormwater management facility or practice, cost must also be an important factor. The responsible designer will not only appreciate this fact, but will also be able to accurately determine and compare the costs of the system and the benefits it provides in order to measure the its true cost effectiveness. To do so, ***the designer has a responsibility to fully understand both the combined cost of system operation and maintenance and the relative benefits or cost savings that can be gained from various design alternatives***. For example, while the use aluminum trash racks or reinforced concrete structures (in place of less durable materials) may increase the client's initial design and construction costs, these increases may be quickly offset by reduced (and recurring) maintenance costs. To accurately perform such analyses requires, among other traits, a high degree of objectivity in order to ensure that the costs and benefits determined by the designer are based upon reality and not the interests or desires of his or her client, supervisor, or government regulator.

4. BMP DESIGN CONSIDERATIONS: POINTS TO PONDER

From the above, it can be seen that ***the responsible stormwater management system designer must not merely be concerned with the technical requirements of a stormwater management program, but must also strive to produce facilities with reasonable and affordable maintenance needs***. The system must also be practical, safe, aesthetically pleasing, and relatively easy and inexpensive to build. The stormwater facilities that result from such an effort will become assets to the community which they serve and will promote the public interest and involvement necessary for overall stormwater program success.

Faced with such a formidable list of requirements, it can be seen that the responsible designer and reviewer must not only bring competent technical ability to the design process, but also an informed, open attitude and even a sense of mission or purpose. To help promote such an attitude and more fully prepare them for the job ahead, the following points regarding stormwater management system design, construction, and operation are offered:

4.1. Interested Parties

To produce a stormwater management facility design good enough to earn an "Approved" stamp from a program reviewer (who is presumably interested in assuring compliance with the program's regulations), a facility designer must identify with those interests and make sure they are reflected on the construction drawings. However, to further ensure that the facility will truly be an asset to the community and will make a positive statement about the value of stormwater management, the system designer must expand this list of interested parties to include the following:

The Client: Including the Client on a list of parties having an interest in a facility's design should not come as a surprise. However, a review of what those interests actually are can be enlightening. Therefore, the responsible designer will not automatically assume to know their client's interests (however obvious they may appear), but will instead fully discuss them with the client.

The prospect of having such a discussion should then lead the responsible designer to ask the following questions:

- What should the client's interests be?
- Does the client fully understand the long term operation and maintenance costs which sometimes are the owners responsibility?
- Does the client have a misinformed or misguided attitude towards the goals of stormwater management?
- Is this attitude based upon a lack of understanding or information?

In such cases, ***the responsible designer can, through education (and a touch of diplomacy), both expand the client's understanding and improve their attitude towards stormwater management, thereby enhancing the designer's own chances of producing a positive facility design***. This will also provide the designer with an excellent opportunity to educate the client about long term system maintenance requirements and costs which the client may not be aware of or fully appreciate.

The Reviewer: Similar to the Client, this individual is also an obvious choice for an "Interested Party" list. However, once again, the following questions may be raised: What are the reviewer's interests and what should they be? Since a reviewer's check of a BMP design can sometimes stray from the program's technical standards into more subjective areas (due, at times, to a lack of such standards), it is often helpful to know what interests the reviewer has in those areas. Are those interests both in keeping with the goals of the stormwater management program and within the program's (and, therefore, the reviewer's) jurisdiction?

Similar to the client, a facility designer may encounter a reviewer who, through a lack of knowledge or an abundance of incorrect information, either misunderstands the importance of system maintenance, or fails to appreciate the costs and effort required to do it properly, or the consequences of neglecting it. Once again, ***the responsible facility designer can, through education and a competent, comprehensive design, expand the regulator's knowledge, interests, and abil-***

ity, particularly in regard to BMP operation, maintenance, and management.

The Constructor: As noted earlier, one of the key responsibilities of a stormwater management system designer is to transform the system from concept to reality by preparing detailed plans and specifications of how it should be built. It is then up to the constructor to finish the project by actually building the facility from these plans and specifications. Therefore, ***the responsible designer appreciates the efforts of the constructor and does not see their own efforts as an independent exercise, but rather as an integral part of a much larger process***; a process which requires the participation of the constructor and then, ultimately, the operator/ maintainer.

As such, the responsible system designer will recognize and respond to the constructor's interests by producing a well-thought out design that can be constructed as easily and simply as possible. Since this may not always be possible, particularly when faced with complex structures, precise dimensions, or difficult site conditions, ***the responsible designer will also take extra care to bring any difficult or unusual aspects of the design to the constructor's attention prior to the start of construction and will even consult with the constructor during the design phase to mutually devise the best construction technique, material, or sequence***.

Under ideal circumstances, the facility designer will also continue their involvement in the project throughout the construction phase. When contracts are agreed upon by the developer and the designer, the contract should include input from the designer throughout the construction phase of project implementation. The designer should work with the constructor to correct mistakes, address oversights, and develop revised designs as necessary to overcome construction problems that were encountered in the field or that may become maintenance problems in the future. It is usually very advantageous to the project for the designer(s) to be in the field to interpret the design at all critical points in the construction. This need is especially acute when the contractor does not have substantial experience building the precise type of project, or when there are any complex elements at all in the design.

The Maintainer: Once construction of the stormwater system has been completed, the designer's involvement with the process (assuming it lasted through construction) normally ends. However, as described above, there are interested parties whose involvement with the facility is just about to start and whose interests the designer must also consider. These are the maintenance personnel who will be responsible for mowing the grass, removing the sediment, clearing the debris, managing the habitats, and performing the necessary repairs at the facility for the rest of its serviceable life. Similar to the constructor, the maintainer's actions will be governed by what the designer creates on paper. However, since construction has been completed and the designer has moved on to other projects, it will be considerably more difficult for the maintainer to have deficiencies or oversights in the design corrected.

As such, ***it is vital that the designer understand and address the interests of the maintainer before it is too late***. As described in greater detail throughout this chapter, this can be accomplished by designing a facility that, optimally, requires a minimum amount of maintenance that can be performed as easily as possible.

The Resident: As described above, this interested party may also be the worker, commuter, shopper, student, or local government official who will interact with the stormwater management system on a regular basis once construction is completed and maintenance begun. This interaction may be physical (through the sense of touch, sight, hearing, or smell) or psychological (as anyone who has worried about their children's safety or the value of their property will know).

In any case, these are the people who most likely have the strongest interest in seeing that a positive facility design is achieved. These are also the people who may soon be asked to participate in the community's nonstructural stormwater management programs by changing some of their aesthetic values and life styles, and who will be paying for the facility's maintenance through their drainage fees, owner association fees, rents, leases, or purchases. Therefore, the facility designer must be aware of their interests and incorporate them into the design plans and specifications.

4.2. Operating Conditions

Just as there are a wide range of people with an interest, either direct or indirect, in the design of a stormwater management system, there is also a wide range of conditions under which it must operate. However, just as the designer may fail to recognize all of the design's interested parties, he or she may also fail to consider all of the real world conditions under which the facility must operate. Instead, ***many designers focus solely on the design conditions necessary for official program approval***.

This is unfortunate, since these design conditions, which may receive all of the designer's attention, will in reality only occur during a small fraction of the system's serviceable life. However, its performance during the remainder of its existence, while ignored by some designers, can largely determine both the amount and frequency of required maintenance and the conditions under which it must be performed. How the system "performs" under these non-design conditions may also largely determine the community's opinion of it and the stormwater program it represents.

Therefore, it is important that the stormwater management system designer be aware of all the weather and other site conditions that the facility will be subject to, including:

Design Conditions: These are obviously the designer's first concern and, as noted above, are normally established by the community's stormwater management program. ***In the case of runoff quantity control, these conditions usually include either a single or range of relatively extreme storm events, the runoff from which must be stored and released at a predetermined rate***. For example, New Jersey's Stormwater Management Regulations require that the runoff from a proposed land development site for the 2, 10, and 100-year storm events be controlled so that the peak rate of runoff after development for each storm does not exceed the peak rate that existed prior to development. The Somerset County, New Jersey standards are more strict, requiring a peak rate after development that is actually <u>less</u> than existing to account for development induced changes in runoff volume and overall hydrograph shape as well.

In the case of stormwater quality control, typical design conditions may include the temporary storage and slow release of the runoff from a much smaller, more frequent storm event in order to promote pollutant removal through sedimentation. For example, New Jersey's Stormwater Management Regulations require the temporary storage of runoff from a 1-year storm event, with release occurring over 18 to 36 hours depending upon the character and intensity of the proposed development. Delaware's stormwater program requires extended storage of the first inch of runoff from a proposed site, with release occurring over 24 hours. Stormwater quality BMPs in Florida are designed to treat up to the first two inches of runoff, with release occurring between 24 and 120 hours. In the Puget Sound Basin, the runoff volume or rate, depending on BMP type, from the 6-month, 24-hour "water quality design storm" is the basis for sizing treatment practices.

Whatever exact design conditions the stormwater management program may specify, it is vital that the structural BMP function properly under them or the goals of the program cannot be met.

Extreme Conditions: In addition to the program's design conditions, which have been selected with the goal of runoff quantity and/or quality in mind, the responsible system designer must also recognize that more extreme storms will also eventually occur. Therefore, ***due to the inherent dangers of storing runoff and the exceptionally large quantities of runoff that can be produced by these extreme events, it is vital that the designer also address the goal of safety by ensuring that the facility will also function properly under such extreme conditions***. Extreme conditions may be defined as either extreme weather or storm conditions where rainfall exceeds normal design values or where equipment or components fail structurally or operationally.

Addressing extreme conditions at a stormwater management system will typically include the provision of an emergency spillway or other auxiliary outflow device that will safely convey the extreme event runoff that exceeds the capacity of the facility's normal outflow structure. It will also include protection of critical portions of any embankment, dam, or discharge points that may be subject to scour or erosion from the high flow velocities generated by this storm event. Protection of such critical areas from damage will not only increase safety but reduce and even eliminate the need for post-storm maintenance and repairs.

Consideration of extreme conditions is also important when reviewing the accessibility of system components to maintenance personnel. For example, if a trash rack is blocked or damaged during a storm event and is causing dangerous water levels in a facility, will maintenance personnel be able to reach it safely? Will inspectors be able to reach the system itself during an extreme storm event to evaluate the potential for overtopping and failure? These questions can only be answered satisfactorily if the facility's performance under such extreme conditions is thoroughly analyzed by the designer.

Dry Weather Conditions: While extreme storm conditions can be expected to occur periodically, a common operating condition at a stormwater management system will be dry weather with various seasonal temperatures, winds, humidities, and periods of daylight. However, while dry weather may be the most prevalent operating condition and the one during which most maintenance will be performed, it is also the one that is most frequently overlooked by the system designer. As a result, how the facility will look, smell, and even sound during the majority of its operating life is then left to chance. This can be particularly unfortunate for the system maintainer and, perhaps more critically, the resident, worker, or commuter who, knowing when to come in out of the rain, will interact most often with the BMP during dry weather conditions. This is especially true if the stormwater system is a multipurpose dry practice. As a result, ***the responsible BMP designer will not only address design and extreme storm conditions, but will also make sure that the facility also performs satisfactorily when it isn't raining at all***.

4.3. Design Methodologies

Prior to starting the actual design, the responsible stormwater management facility designer will have an adequate understanding of the design methodologies that have been selected or required. These methodologies can cover such aspects as rainfall-runoff computations, hydrograph routings, infiltration and ground water movement, structural design, and geotechnical issues. In doing so, the designer's understanding should include each methodology's theoretical basis, assumptions, limitations, and applicability.

In addition, the responsible designer will also have an understanding of both the accuracy needed to perform the design and the accuracy of the method selected to do it. From this information, the responsible designer will not waste time producing unneeded accuracy nor attempt to achieve a level of accuracy beyond the limits of the method. In addition, the responsible designer will understand the sensitivity of each of the method's input variables and will appropriately allocate his or her efforts, time, and resources in developing each one.

Finally, the responsible designer will understand the applicability of each methodology to the design of such maintenance-related items as bottom and side slopes, trash racks, erosion protection measures, low flow channels, forebays, and outlet works.

4.4. Facility Type

The final point for a stormwater management facility designer to consider before or during the design process is the exact type of practice to be used. There are typically a wide range of stormwater management practices available for consideration, ranging from relatively simple vegetated filter strips and swales to large wet ponds and constructed wetlands. However, ***selection of the most appropriate type of facility may have a greater impact on maintenance effort than all other factors combined***.

Selection of the most appropriate stormwater BMP will depend upon a number of factors, including program requirements, facility location, site conditions, maintenance needs, safety, cost, and performance characteristics. Similar to that of selecting/determining facility operating conditions, however, the facility designer may often consider only a few of these factors, most notably program requirements (keep the reviewer happy and get the approval) and cost (keep the client happy, too). The ***responsible designer, however, will recognize the performance, construction and maintenance needs, uncertainties, and risks inherent in each facility type and will then select (or help influence the selection of) the most appropriate type of system for the site or project***. This process typically begins with the identification of the fundamental characteristics of each type of stormwater management practice, along with the project's physical, economic, social, and regulatory constraints. The process then becomes one of comparison and analysis, with the best match of site and facility found by eliminating those options least suitable.

For example, a site with porous soils, low ground water table, and close proximity to residences may not be best suited for a wet pond or constructed wetland, while the active recreational needs of the residents may benefit from an infiltration basin or dry, extended detention basin that can also serve as an athletic field. In addition, the maintenance needs of these two practices should be well within the homeowners' abilities, while a constructed wetland may require expensive maintenance expertise far beyond both the homeowners' ability or budget. ***Recognizing that there are rarely perfect matches, comparisons and analyzes such as this will help reduce the***

Minimum maintenance performed at maximum efficiency should be a goal of every stormwater facility planner, designer, and reviewer.

number of potential facility types, improve the thoroughness and objectivity of the overall selection process, and ideally produce the optimum stormwater system, not only from a performance or regulatory viewpoint, but from a maintenance viewpoint as well. This process can even help identify inherent weaknesses in or problems with the selected BMP or exceptional maintenance demands. This will enable the responsible facility designer to devote additional time and effort towards correcting or minimizing them during the design phase.

To undertake such a selection process obviously requires a stormwater designer who understands the fundamental characteristics and needs of each facility type and who can objectively assess all of the pertinent site constraints. Such a designer must also be willing and able to address the differing opinions of other, less objective or informed parties (including the reviewer, client, or member of the public) in order to assure that the best practice is ultimately selected. As noted throughout this chapter, ***achieving an optimum stormwater management facility design is a complex and demanding process which must incorporate numerous interests and requirements. Starting the process with the wrong facility type, however, transforms a complex and demanding process into an impossible one***.

5. BMP DESIGN CONSIDERATIONS: A CHECKLIST

Having completed the BMP practice selection process with idealism, and design contract still intact, and armed with the necessary technical and regulatory knowledge and economic, social, and maintenance sensitivity, the responsible stormwater system designer is ready to begin the actual design process. ***Presented below is a checklist of six key design considerations to help guide this effort, with particular emphasis placed upon long term facility maintenance. Ideally, these six items have or will become an integral part of the designer's thought process and will automatically be included in each design effort***. These items can also serve as guidelines for reviewers responsible for the review and approval of specific system designs and can even serve as goals for those developing new stormwater management programs.

5.1. Safety

For many reasons, the safety of the stormwater management system must be the primary concern of the designer. Due to its structural nature and, in many instances, the fact that it will impound water either permanently or temporarily, a stormwater facility will inherently pose some degree of safety threat.

Those at risk will include people living, working, or travelling downstream of the system and whose safety and/or property will be jeopardized if the facility were to fail and release stored runoff. Since this is a risk that has been created solely by the system, the designer must assure that the probability of such a failure is acceptably small.

However, also at risk at the facility are maintenance personnel, inspectors, mosquito control personnel, and equipment operators, who must work in and around it. Typical hazards include deep water, excessively steep slopes, slippery or unstable footing, limited or unsafe access, and threats posed by insects and animals. As noted above, ***the responsible stormwater designer understands the importance of minimizing and facilitating facility maintenance. Providing a safe working environment for the system maintainer is one important way to do it***.

Finally, those living, working, traveling, attending school, or playing in the vicinity of a facility may also be at risk, particularly if the system serves both as a stormwater management and recreational facility. Once again, such things as standing water, steep slopes, unstable footings, and insect and animal bites must be addressed by the designer in order to avoid creating a system that is a detriment to the community it is intended to serve. Failure to do so will only alienate those members of the community that are being asked to play a vital role in the community's stormwater management efforts.

5.2. Performance

Having made a strong commitment to safety, the designer must then consider facility performance. This will normally include achieving the necessary stormwater detention times, flow velocities, settling rates, peak flow attenuation, and/or ground water recharge for the range of storm events to be managed. In addition, again with a commitment to safety, the designer must also ensure that the system performs adequately under emergency conditions, most notably when the peak rate and/or volume of runoff flowing into the basin exceeds the discharge capacity of the facility's principal outlet. This will require the inclusion of emergency or auxiliary outlets in the facility to safely convey this excessive inflow through the BMP without jeopardizing its structural integrity.

In most instances, the performance standards that the system's design must meet will be specified in the stormwater management program's regulations. However, experience has shown that these performance standards may, at times, be vague, contradictory, or even impossible to meet. For example, many stormwater system designers have been confronted with a requirement to reduce both the peak rate <u>and</u> total runoff volume from a developed (or developing) watershed to predeveloped levels. This has often led to much head scratching, for the solution will normally require the use of an infiltration or recharge basin which, due to site constraints, may either be impossible to construct or impractical to operate and maintain. Or the regulations may require high sediment removal rates but preclude the use of low flow channels that can greatly facilitate the sediment's removal by maintenance personnel. ***Faced with such circumstances, the responsible designer will look beyond the written regulations and investigate their origins and true intent with regulatory personnel. Direct inclusion of these individuals in the design process will also help ensure more positive overall results***.

5.3. Constructability

Up until now, the designer's efforts to achieve adequate facility safety and performance levels will be achieved only on paper or computer disk. However, ***since the ultimate goal of the design process is to actually create a stormwater management system, the designer must also give careful consideration to how it is to be constructed***. Achieving exceptional safety and performance characteristics in a system that cannot actually be built solves nothing and wastes much. Achieving required levels of safety and performance in a facility that can be constructed with relative ease, using readily available materials, equipment, and skills is commendable. It not only solves a specific stormwater management problem, but also helps to advance the community's overall stormwater management program.

"Constructability" can be defined as a measure of the effort required to construct a stormwater management system. A facility that is highly "constructible" will use materials that are readily available, relatively inexpensive, and do not require special shipping or handling measures. They will be both durable and easily modified in the field to meet specific site conditions. Similarly, the construction techniques and equipment required to construct the system will also be relatively simple, straight forward, and familiar to the people who will be performing and operating them.

In addition, construction plans and specifications should be complete, clear, and concise. They should be well organized - with all of the necessary information regarding a specific facility component or construction stage provided on a single or adjoining sheets. All new or more difficult techniques, stages, or components should be given extra attention, with ample instructions, notes, and details.

It is important to note that the above description is <u>not</u> intended to discourage the use of new or innovative materials or construction techniques, nor to inhibit creativity in the stormwater system design process. In fact, ***innovation in design and construction is vital to the future growth of stormwater management***. Instead, the above description of "constructability" is intended to remind designers that they must consider the construction aspects of the BMP in the design process and strike an optimum balance between performance and safety requirements, constructability, and innovation for each design they undertake. In addition, ***the more well-constructed a stormwater management facility is, the less overall maintenance and repair it will require***.

5.4. Maintenance

Obviously, in a handbook on stormwater management system operation and maintenance, the same recommendation, given above for constructability, must be repeated for facility maintenance. Similar to construction, the degree of effort and expense required to adequately maintain a stormwater management system will help determine the overall success of its design. A system with manageable maintenance needs can be expected to remain in reasonably good condition and will have a stronger chance to become and remain an asset to the surrounding community. On the other hand, a facility with excessive maintenance needs is more likely to be neglected and will quickly become a community liability. As such, ***BMP operation and maintenance can directly effect the overall success of the community's stormwater management program***.

The stormwater designer can help determine a facility's maintenance needs by considering several aspects of that maintenance in the design process. First, it is important that the system design include the ***use of durable materials*** that are able to withstand the many and varied physical conditions the facility will experience over its lifetime. Secondly, ***suitable access to key facility components and areas is vital*** if required maintenance levels are to be achieved. This will include provisions for walkways, staging and disposal areas, access hatches and gates, and safe, stable working areas. The frequency of maintenance will have a large impact on both maintenance cost and quality, and it is the designer's responsibility to achieve an appropriate level. Finally, the ***system designer should always strive to minimize the overall amount of maintenance at the facility and to make that amount as easy as practicable to perform***. A more detailed discussion of maintenance considerations during system design is presented in the following section.

5.5. Cost

Inclusion of a stormwater management system's cost in a list of design considerations should not be surprising. However, once again, a review of the full costs associated with a facility may yield a few surprises that may increase designers' understanding and encourage them to give system costs the full consideration they deserve. ***Where costs are surprising, the designer should communicate with the local regulatory agency to ensure that the costs are "real" and to make the regulatory agency aware of the economic impacts of pertinent program requirements***.

The cost that will be most obvious to the designer will be the systems's construction cost. This can be readily estimated with reasonable accuracy and will be the one most directly borne by the designer's client. As such, this cost is the one that the designer will most often focus on during the design process to the exclusion of all others.

In doing so, what other costs will be overlooked? One may be the designer's own fee, which is part of the overall system cost but which has probably been excluded because it has already been determined. However, the amount of the designer's fee will have a direct impact on the facility design, since it will determine the amount of effort and resources the designer can/will use to produce it. The level of effort expended during the system's design can have a similarly direct effect on the effort and cost of both construction and maintenance. As such, it can be seen that ***paying a higher cost for a more comprehensive facility design may ultimately result in even greater cost savings to the client during subsequent project stages***.

Therefore, while this is <u>not</u> a signal to facility designers to raise their fees, it is meant to remind designers that their fee <u>is</u> part of the overall system cost. It is their responsibility to determine what level of design effort and cost represents the best investment for both the client and the community.

Another portion of a system's total cost that is frequently overlooked is the cost associated with its operation, maintenance, and management. ***While the annual cost is usually a small percentage of the construction or even the design cost, it must be remembered that, unlike construction or design, OMM costs are recurring and must be paid throughout the life of the system***. Therefore, while a maintenance cost savings may appear to be insignificant on a per operation basis and not worth the extra design or construction costs required to achieve it, value may be viewed quite differently when multiplied by the numerous times the savings will be realized. For example, an added investment in design to produce a trash rack that will require less frequent cleaning or an added investment during construction to reduce the frequency of outlet structure repairs may quickly yield a positive return in the form of reduced maintenance costs. Similar conclusions can be reached for many other design and construction efforts, such as providing better access, using more durable materials, and selecting a BMP type that best suits site conditions.

5.6. Community Acceptance

The final recommended design consideration once again involves those people who may have the greatest interest in the stormwater management system: the community. Not coincidentally, these same people will have the greatest role in funding the facility's maintenance and will ultimately have the greatest role in the various nonstructural programs intended to augment stormwater management systems in the future. To protect these interests and encourage assumption of that role, ***it is up to the designer to help create a facility that will be viewed as a community asset rather than a liability***.

As discussed above, this can be achieved only by considering the system's aesthetic value, preventing the creation of nuisances and safety threats, minimizing and facilitating facility maintenance, as well as achieving required performance levels. It is only through all of these factors that stormwater management will gain the understanding and credibility it requires within the community.

6. SPECIFIC MAINTENANCE CONSIDERATIONS

To further help stormwater management planners, designers, and reviewers include system maintenance in their everyday thinking, three specific maintenance considerations have been developed. These considerations, which were originally developed for the New Jersey Department of Environmental Protection's Stormwater Management Facility Maintenance Manual, should ideally come to mind whenever a stormwater management practice is pondered, planned, designed, or reviewed. The facility designer should pretend that they must do the maintenance to see if access and maintainability are provided.

6.1. Maintainability

Maintainability can be expressed in three ways, all of which should be given equal importance by facility designers and reviewers:

- Every effort should be made to minimize the amount and frequency of regular maintenance at a stormwater management system.
- Performance of the remaining maintenance tasks should be as easy to perform as possible.
- All efforts should be made to eliminate the need for emergency or extraordinary maintenance at the facility.

Recommended techniques for accomplishing these goals, which can be used to both select the most appropriate type of BMP, as well as design and review it, are presented below.

6.2. Accessibility

According to many maintenance personnel, the biggest problem they encounter is not the amount or frequency of maintenance they must perform, but the difficulties they have in simply reaching the location of the required maintenance work. In order for proper maintenance to be performed, the various components of the stormwater system and, indeed, the facility itself, must be accessible to both maintenance personnel and their equipment and materials. Physical barriers such as fences, curbs, steep slopes, and lack of adequate and stable walking, standing, climbing, and staging areas can seriously hinder maintenance efforts and drastically increase maintenance difficulty, cost, time, and safety hazards. Amenities such as depressed curbs, hand and safety rails, gates, access roads, hatches, and manholes will expedite both inspection and maintenance efforts and help hold down costs and improve efficiency.

Important design considerations for components such as gates, hatches, manholes, trash racks, and other components that must be lifted or moved during inspection or maintenance operations, include both the item's weight and a secure place to put it when it's not in its normal location. When weight becomes excessive, mechanical aids such as hoists, lifts, and lifting hooks should be provided. When fastening removable items like trash racks, orifice and weir plates, and gratings, the use of noncorroding, removable, and readily accessible fasteners will also help greatly.

Sometimes design considerations may conflict. For example, in designing access roads, they must have the proper turning radius, slope, and wheel loading to allow cleaning of a pond by heavy construction equipment. The road's storm drain covers, designed for the desired wheel loading, may be too heavy to move easily. Perhaps a different access way may need to be provided.

Finally, ***legal barriers such as lack of access rights or inadequate maintenance easements can stop the best maintenance efforts before they can even get started***. This is especially pertinent to project reviewers, who normally have the authority to require such legal aspects of the project.

6.3. Durability

The use of strong, durable, and noncorroding materials, components, and fasteners can greatly expedite facility maintenance efforts. These include strong, lightweight metals such as aluminum for trash racks, orifice and weir plates, and access hatches; reinforced concrete for outlet structures and inlet headwalls; hardy, disease-resistant vegetation for bottoms, side slopes, and perimeters; and durable rock for gabions and riprap linings. ***In most instances, the extra investment normally required for more durable materials will pay off over time***.

7. SUGGESTED DESIGN REVIEW TECHNIQUES

Throughout this chapter, the stormwater system designer has been encouraged to consider a wide range of interests, operating conditions, costs, and other responsibilities throughout the design process. Presented below are two recommended techniques to help accomplish it. They can either be used as review techniques following completion of a facility design or, ideally, be incorporated into the overall design process and used continually during it.

7.1. Spend a Mental Year at the Facility

To use this technique, ***the stormwater designer or reviewer simply imagines conditions at the completed facility throughout a full year***. This should not only include rainy and sunny weather, but also light rain showers (with little or nor runoff) and, where appropriate, both light and heavy snowfalls and frozen ground conditions. Other site conditions may include late autumn, when trees have lost their leaves and they have collected at the facility bottom, and hot, dry weather or drought, when the turf or other vegetation is stressed or killed. Finally, for safety purposes, the designer should also imagine what the system will be like at night.

As these conditions are visualized, ***the designer should also imagine how they may affect not only the operation of the system itself, but also the people that will maintain it or otherwise interact with it***. Will the outlet structure's trash rack be particularly prone to clogging by fallen leaves, especially from the trees the designer just specified for the facility's bottom? Can falling and/or blowing snow completely fill the facility, leading the unsuspecting snow plower or pedestrian to think that the grade is level? What about the ice that will form on the surface of a pond or constructed wetland? Can someone fall through? Could that someone be a child taking a shortcut home or out looking for a place to skate? How will they be warned not to? How will they be rescued if they do anyway?

What about night conditions? Will the constructed wetland next to the office parking lot that's so attractive during summer lunch hours become a safety hazard to workers walking to their cars in the winter's darkness? Or will that same summer sun and a lack of rainfall produce some of the wonderful aromas of anaerobic decomposition?

At first, it may be exasperating to realize that the number of possible site conditions and circumstances can be as numerous and varied as the number of possible facilities types. But then again, that is the point of this exercise. It is intended to help the designer consider and design for all possible conditions at the facility, not just the 1 or 100-year storm event required by the regulations. In doing so, the facility designer will not only meet the letter of the regulations, but will raise the spirit of the entire stormwater management program.

7.2. Who, What, When, Where, and How?

The second recommended review technique a system designer may employ is to simply focus on one or more characteristic or function of the facility and then ask (and attempt to answer) the above question. For example, let's consider stormwater system operation and maintenance and then ask:

- **Who will perform it?** Does the stormwater system's design require specialists or will someone with general maintenance equipment and training be able to do the job?

- **What needs to be maintained?** Preparing a list of all facility components included in a design that will need attention sooner or later may prompt a revised design with a shorter list.

- **When will maintenance need to be performed?** Once a day? A week? A year? Remember, the recurring costs of system maintenance can be substantial. In addition, can maintenance only be performed during dry weather? If so, what happens during two or three weeks of wet, rainy weather? What happens when repairs need to be made or debris removed during a major storm event? In terms of effort and possible consequences, it is easier for the designer to find answers to these questions now, than for maintenance or emergency personnel to scramble for them later.

- **Where will maintenance have to be performed?** Will the maintainer be able to get there? Once there, will they have a stable, safe place to stand and work? In addition, where will such material as sediment, debris, and trash removed from the facility be disposed of? Before answering that question, do you know how much there might be and what it might contain? Are there toxic or hazardous materials in the sediment or debris? If so, is the place you originally intended to use for disposal still suitable? Once again, it is easier to address these questions now then when the dump truck is loaded and the engine's running.

- **How will maintenance be performed?** The simple instruction to remove the sediment or harvest the vegetation can become rather complicated if there hasn't been any provisions made to allow equipment to get to the bottom of the facility or even into the site. "Mowing the grass" can become "risking your limbs" on long, steep slopes. How will you explain to your client why the stormwater management facility they have invested in has become a liability to themselves and their community?

Similar exercises can be performed with constructors, inspectors, and residents as the object of inquiry. For example, where will the nearest residence be? How will the constructor build the emergency spillway? When will an inspector need to visit to check for mosquitoes?

Similar to the "mental year" review technique, the questions raised in this technique are intended to make the designer more aware of all the possible impacts the facility may have and, further, to encourage the designer to address those impacts now, during the design phase, rather than leave them for others, particularly maintenance personnel, to cope with later. Even if the designer cannot completely answer all of the questions, he or she will be able to advise the others of any unavoidable needs or problems that will be inherent in the facility and allow them time to adequately prepare.

8. DESIGN GUIDELINES

Presented on the following pages are technical design guidelines that are intended to minimize and facilitate maintenance at detention, infiltration, filtration, and biofiltration practices. Separate guidelines are presented for each BMP type. In addition, the guidelines are further divided into each facility's major components for easier reading and reference use. Descriptions of typical maintenance problems at various facility components have also been included to further stimulate the reader's efforts to produce BMP designs that require minimum levels of maintenance effort. The technical guidelines have been based upon similar guidelines presented in the Stormwater Management Facilities Maintenance Manual prepared by the N.J. Department of Environmental Protection.

It is important to note that the guidelines should be used with all other hydrologic, hydraulic, structural, geotechnical, biological, aesthetic, and legal requirements of the stormwater management program governing the design of a particular facility or practice. As such, they are not meant to conflict or replace these requirements but, instead, to complement and expand them. Finally, a responsible designer understands that each project and facility site is unique and may require special, additional, or more strict measures.

9. SUMMARY

Stormwater management must still be considered a relatively new endeavor, particularly on a nationwide basis. However, despite that status, it has been charged with the responsibility of addressing some very complex environmental problems. In order for stormwater management to grow to the level demanded by this charge, the designers of stormwater management facilities must be willing to assume a degree of responsibility for that growth. ***BMP designers can fulfill that responsibility by producing facility designs that do not merely meet official regulations and standards, but help inspire new, better, and more comprehensive ones***.

Facility designers must also incorporate a wide range of interests into the facility design, including those held by stormwater program regulators, contractors, maintainers, and those members of the community interacting with the facility and paying for its long term maintenance. During the design process, the facility designer must not only consider the facility's performance, but also the extent, frequency, difficulty, and cost of facility maintenance. Finally, the BMP designer must always recognize the facility's impacts both on the community around it and the stormwater management program the community has entrusted them with.

10. DESIGN GUIDELINES FOR DETENTION PRACTICES

10.1. INTRODUCTION

The following technical design guidelines are intended to help planners, designers, and reviewers produce stormwater detention systems that require minimum levels of maintenance. Typical detention practices include:

- **Dry Detention Basins**
- **Extended Dry Detention Basins**
- **Wet Detention Basins or Ponds**
- **Subsurface Detention Facilities**

To help accomplish this minimum maintenance goal, the design guidelines have been developed to:

1. **Eliminate avoidable maintenance inspections, tasks, and problems.**

2. **Minimize the long term amount of regular facility maintenance.**

3. **Facilitate required maintenance inspection and tasks.**

4. **Reduce the potential for extensive, expensive, and often difficult remedial or emergency maintenance efforts.**

It is important to note that ***these design guidelines are intended to supplement all other applicable facility design standards and requirements, including those pertaining to a facility's hydrologic, hydraulic, structural, geotechnical, environmental, legal, and aesthetic aspects. As such, they should be used creatively with all other applicable standards and requirements to produce stormwater detention systems that require optimum levels of maintenance performed with the least practical effort, time, and expens***e. Those involved with the planning, design, and review of specific stormwater management systems must assume their share of the responsibilities for a system's performance, longevity, and safety.

To assist in their use, the technical design guidelines are presented separately for each major facility component as listed in Table 3-1. Complete descriptions of each type of detention BMP are presented in Chapter 2.

Descriptions of typical maintenance problems encountered at each facility component are also described. These descriptions, which have been based upon facility inspections and interviews with maintenance personnel, highlight the types of maintenance problems that the design guidelines are intended to prevent or minimize. They should serve to further stimulate planners, designers, and reviewers to develop additional, improved, and/or site-specific designs.

10.2. BOTTOMS

A. Dry and Extended Detention Dry Facilities

In a study performed by the N.J. Department of Environmental Protection, facility bottoms were the most likely location of chronic maintenance problems at dry and extended dry detention facilities. Typical problems that impede or unnecessarily increase proper facility maintenance include:

- **Standing Water**
- **Soggy Surfaces**
- **Poor Grass Growth**
- **Excessive Sedimentation**
- **Limited Access**

1. To promote complete emptying and prevent standing water or soggy surfaces, vegetated bottoms should have a minimum slope

of 2 percent and be graded to the outlet structure or low flow channel.

2. To promote complete emptying and prevent standing water or soggy surfaces, the lowest point in the bottom should be at least 4 feet above the seasonally high ground water level or bedrock unless adequate subsurface drains are provided.

3. To provide adequate drying time, to avoid delaying scheduled maintenance efforts, and to prevent mosquito breeding, the maximum storage or ponding duration should not exceed 24-48 hours, depending on the vegetation's tolerance to wetness.

4. To avoid delaying scheduled maintenance efforts, topsoils and subsurface soils should be sufficiently permeable to allow rapid infiltration, evaporation, and evapotranspiration.

5. Subsurface drains connected to the principal outlet structure, low flow channel, or other discharge point are encouraged to promote quick and thorough drying of the facility bottom. In doing so, care should be taken to prevent stormwater inflow from inadvertently bypassing the basin's outlet controls. (See **G. LOW FLOW MEASURES** for additional details.)

6. To minimize routine grass maintenance such as mowing and fertilizing, the use of native grass varieties that are relatively slow growing and tolerant of poor soil conditions are encouraged. Information on native grass varieties and mixtures are available from agencies such as the local Cooperative Extension Service or Soil Conservation District. (See **H. VEGETATIVE COVER** for additional details.)

7. To promote lasting growth, grasses and other vegetative covers should be compatible with the prevailing weather and soil conditions and tolerant of periodic inundation and runoff pollutants. (See **H. VEGETATIVE COVER** for additional details.)

8. To facilitate removal efforts, sedimentation should be promoted at localized, readily accessible areas. Sediment traps or forebays at inflow and outflow points should always be used. Those lined completely or partially with smooth materials such as reinforced concrete can be more readily cleaned. For these reasons, the exclusive use of loose stone, riprap, and other irregular linings which require manual removal of weeds, sediment, and debris should be avoided wherever possible.

Forebays trap sediment and debris before it enters the facility in areas that can be more readily cleaned.

9. Wherever possible, sediment disposal and storage areas should be provided adjacent to the facility. These areas should optimally be designed to contain removed sediment, on a long-term basis.

10. Suitable access for maintenance personnel and equipment needs to be provided to the facility bottom. (See **J. ACCESS** for details.)

11. Construction plans and specifications should include provisions that minimize the potential for localized settlement and subsequent ponding. These provisions include

Access to all areas of the facility by both personnel and equipment is vital to successful maintenance.

proper surface and subsurface soil characteristics, compaction requirements, grading equipment, and erosion control prior to the establishment of permanent vegetative cover.

12. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

13. At subsurface detention facilities, suitable access, observation points and/or monitoring wells should be provided to facilitate inspection and cleaning. (See **J. ACCESS** for additional details.)

B. Wet Detention Facilities

While unseen, wet detention system bottoms collect sediment and other material at a much faster rate than their dry counterparts. Removal of this material can be difficult and expensive. Other problems may arise in the aquatic ecosystem as well. Typical problems that impede or unnecessarily increase proper facility maintenance include:

- **Poor Water Quality**
- **Limited Access and Staging Areas**
- **Non-Permanent Pool**
- **Excessive Sedimentation**

1. In order to promote a healthy aquatic ecosystem, the minimum permanent pool depth should be 4 feet or greater. On the other hand, it should not be so deep as to allow thermal stratification to develop in the summer, with the resultant likelihood of anaerobic conditions developing in the bottom stratum. Depth should be limited to that at which small lakes in the vicinity stratify; 8 feet maximum is probably a widely applicable limit.

2. Design of a wet detention system should include the determination of the proposed site's ability to adequately support a viable permanent pool with an equally viable ecosystem. The design should account for such factors as the required rate and quality of dry weather inflow, the quality of stormwater inflow, seasonal and longer term variations in the ground water table, and the effects of expected sediment and other pollutant loadings. In the highly seasonal climates of the West Coast, it may be appropriate to design for a semipermanent wet pool, which gradually dries in the summer.

3. The establishment of predacious native (if possible) fish species in the permanent pool will help control mosquito breeding, but introduction of nonnatives or fish not already established in the area should be avoided.

4. Provisions to drain the permanent pool are necessary for maintenance and safety. A gravity drain is the preferred method. If this is not feasible, suitable pumps and both primary and backup power sources should be provided. To ensure that they are available when needed, all pumps and backup power sources should be reserved for facility use only. In residential communities, pumps may only be allowed to run during daytime hours due to noise. This needs to be considered when determining times for the drainage to occur.

5. To promote complete emptying of the permanent pool when necessary, the bottom should have a minimum slope of 2 percent and be graded to the outlet drain or pump intake.

6. Water quality, including suitable oxygen levels, should be maintained through continuous recharge with fresh water from natural surface or subsurface sources. Alternatively, orienting the detention system to take advantage of prevailing winds can help to promote aeration and circulation. Mechanical aeration should be relied upon only when absolutely necessary.

7. To facilitate removal efforts, sedimentation should be promoted at localized, readily accessible areas upstream of the permanent pool. The BMP Treatment Train is strongly recommended for wet detention systems, especially if they are to be promoted as "lakes" and serve as an aesthetic and recreational amenity for the development. Swale conveyances and sediment traps or forebays at inflows are encouraged. Those lined completely or partially with smooth materials such as reinforced concrete can be more readily cleaned. For these reasons, the exclusive use of loose stone, riprap, and other irregular linings which require manual removal of weeds, sediment, and debris should be avoided wherever possible.

8. Wherever possible, sediment disposal and storage areas should be provided adjacent to the facility. These areas should optimally be designed to contain 5 years or more of removed sediment.

9. Suitable access for maintenance personnel and equipment should be provided to the facility bottom to allow proper use of equipment that is used by the maintainer. (See **J. ACCESS** for details.)

10.3. DAMS, EMBANKMENTS, AND SIDE SLOPES

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Steep Slopes**
- **Long, Continuous Slopes**
- **Poor Grass Growth**
- **Sloughing and Erosion**

1. For safe movement of maintenance personnel and safe operation of equipment, side slopes greater that 5 feet in height should not be steeper than 4 horizontal to 1 vertical. Side slopes less that 5 feet high should not exceed 3 horizontal to 1 vertical. Flatter side slopes are recommended wherever possible.

Mild side slopes allow maintenance personnel to perform their jobs quickly and safely.

2. For safe movement of maintenance personnel and safe operation of equipment, side slopes steeper than 5 to 1 and higher than 15 feet should be terraced at their midpoints. The terrace should have a minimum width of 3 feet and should be graded at 2 percent or flatter towards the lower half of the slope.

3. Suitable access to and along side slopes should be provided for maintenance personnel and equipment. (See **J. ACCESS** for details.)

4. Topsoil and vegetative covers must be protected from erosion caused by local runoff and the slope's steepness. Surface and subsurface soil stabilization measures or nonvegetated linings should be used as necessary. In doing so, avoid the use of loose stones, riprap, and other irregular lining materials which require hand removal of weeds and debris and may be a safety hazard to maintenance personnel walking along or up the slope.

5. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

6. The effects of rapid pool drawdown should be checked to prevent side slope sloughing.

7. For safe movement of maintenance personnel and safe operation of equipment, fences should not be constructed within 3 feet of either the top or toe of any side slope that exceeds 5 horizontal to 1 vertical.

Adequate distance should be provided between the top of a slope and adjacent structures such as fences, walls, curbs, or roadways.

8. Below the permanent pool level at wet detention facilities, a 4-foot to 10-foot wide level area or safety ledge should be provided to prevent people or objects from sliding or falling into deeper water. This area can be used to create a vegetated littoral zone along the shoreline. The vegetated littoral zone provides biological processing of dissolved pollutants, requires less regular maintenance than a grass shoreline, and provides habitat for predacious insects, fish, and birds which control mosquito breeding.

9. Durable linings such as gabions or riprap need to be considered along wet detention system shorelines prone to erosion due to excessive wave action or ice movement. Such linings should extend sufficiently above and below the permanent water level to account for wave and ice run-up.

Good shoreline erosion protection is vital for facility maintenance and safety.

10.4. PRINCIPAL OUTLETS

Typical problems that impede or unnecessarily increase proper maintenance include:

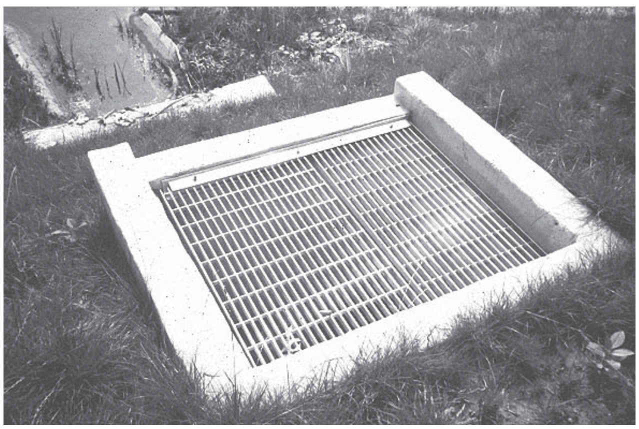
- **Structural Deterioration**
- **Limited Access**
- **Corroded Appurtenances**
- **Vandalism**
- **Excessive Debris Accumulation**

1. For durability, principal outlet structures should be constructed of reinforced concrete containing Type II cement and having a minimum specified 28-day compressive strength

of 3,000 PSI. Concrete shall be designed in accordance with all applicable codes and requirements.

2. For durability, all appurtenances, including access hatches, trash racks, gratings, railings, orifice and weir plates, and fasteners should be constructed of lightweight, noncorroding materials. Material strengths should be sufficient to withstand design loads without damage or failure.

Outlet structure gratings, trash racks, and other appurtenances should be lightweight, durable, and removable.



3. Outlet orifice and weir plates should be constructed from aluminum or other lightweight, noncorroding material. The plates should be fastened to the structure with noncorroding, removable fasteners. A gasket of neoprene or similar material should be placed between the plate and the structure wall. The opening in the structure wall over which the plate is bolted should have at least twice the area of the outlet orifice or weir to facilitate field adjustments and future expansion. See Figure 3-A at the rear of this chapter for details.

4. To facilitate access and movement by maintenance personnel, principal outlet structures should have a minimum horizontal interior dimension of 4 feet. (See **J. ACCESS** for additional details.)

5. Vital parts of the principal outlet structure should be readily and safely accessible to maintenance personnel during both normal and emergency conditions. Gate valves should be able to be operated in the dry when the maximum design water level occurs. Temporary measures such as ladders are only acceptable for emergency conditions as part of an approved emergency action plan. (See **J. ACCESS** for additional details.)

6. To minimize both required maintenance and the consequences of inadequate maintenance, principal outlets should avoid using moving or mechanized parts for outflow control whenever possible.

7. To facilitate cleaning, outlet pipes should have a minimum diameter of 15 inches. The pipes should be constructed of durable materials, such as reinforced concrete. To minimize potential leakage problems, the number of outlet pipes should be kept to an absolute minimum. More than one outlet pipe should be used only where unavoidable. All outlet pipes must be watertight under the maximum expected head or pressure.

8. Grading and landscaping around principal outlet structures should be designed to facilitate mowing, trimming, debris removal, and other general maintenance tasks. Grassed slopes which require mowing should not exceed 3 horizontal to 1 vertical. Vegetated cover which does not require mowing or nonvegetated linings should be used where steeper slopes are necessary.

9. Stable areas that provide maintenance personnel with firm footing should be provided at the upstream face of principal outlet structures at dry and extended dry facilities. Linings such as reinforced concrete, gabions, and grouted riprap should be considered.

10. All nonvegetative linings which are bordered by grass should be designed to permit

complete mowing along all edges.

11. Dry weather flow through a principal outlet structure should not interfere with routine interior maintenance tasks. Benching, low flow pipes and channels, drop structures, or similar measures should be used to convey low flow into and through the structure.

12. Principal outlet structures should be designed to discourage vandalism and graffiti. The use of aesthetic type vegetation to cover walls is encouraged.

10.5. OUTFLOW SYSTEMS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Clean**
- **Erosion and Scour**
- **Excessive Sedimentation**
- **Displaced Lining**

1. The outflow conveyance system downstream of a detention system should have adequate capacity to accommodate its outflows. This will not only allow design outflows and water surfaces to be attained, but will also help achieve required drawdown and emptying times.

2. Outflow velocities should be high enough to prevent sedimentation and low enough to prevent erosion and scour.

3. Manholes, grates and other suitable access points should be provided for cleaning and inspection. (See **J. ACCESS** for additional details.)

10.6. INLETS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Clean**
- **Erosion and Scour**
- **Excessive Sedimentation**
- **Displaced Lining**

1. The number of inlets to a detention system should be kept to a minimum. This will minimize the amount of required downstream lining, forebays, and low flow channels. All inflow pipes and culverts should terminate at a headwall or flared end section with adequate cutoff walls. Inlet pipes or channels should be placed on a minimum slope to prevent high entrance velocities. If high velocities can not be avoided, the designer should consider riprap inlet protection to prevent erosion and baffling to slow flow and guard against short circuiting to the outlet.

Facility inlets must terminate with a headwall or flared end section to prevent scour and provide stability.

Inlets should be located to prevent or minimize flow short-circuiting. If inlets and outlets cannot be spaced so that the flow path length is at least three, and preferably, five times the average width (dimension perpendicular to length), the designer should attempt to lengthen the flow path by moving the inlet and/or outlet or using baffles to divert flow. Another excellent impediment to short circuiting is dividing the system into two cells with flow restricting to passing through a single point between them.

2. Linings placed downstream of facility inlets should accommodate design flows without erosion or scour. They should also facilitate removal of sediment, trash, debris, and undesirable vegetation.

3. Forebays and other localized sediment and debris traps should be placed immediately downstream of facility inlets. Where practical, avoid loose stone, riprap, and other irregularly shaped linings which require hand removal sediment, trash, and debris. (See **A. BOTTOMS** for additional details.)

4. The BMP Treatment Train approach should be used to minimize sediment entering the facility. Street sweeping, offsite soil stabilization measures, and upstream sedimentation basins, swales, and other source control BMPs can significantly reduce the frequency of required sediment and trash removal operations.

5. To facilitate cleaning, inflow pipes should be a minimum diameter of 15 inches. The pipes should be constructed of durable materials, such as reinforced concrete, ductile iron, or PVC. Inlet pipes should not have trash racks placed on them at their outlets into the pond to prevent plugging of the inlet and water backing up into the site drainage system.

6. Grading and landscaping around facility inlets should be designed to facilitate mowing, trimming, debris removal, and other general maintenance tasks. Grassed slopes which require mowing should not exceed 3 horizontal to 1 vertical. Vegetated cover which does not require mowing or nonvegetated linings should be used where steeper slopes are necessary.

7. Stable areas which provide maintenance personnel with firm footing should be provided at facility inlets. Linings such as reinforced concrete and gabions should be considered.

8. All nonvegetative linings which are bordered by native grass should be designed to permit complete mowing along all edges.

9. Dry weather flow from a facility inlet should not interfere with routine maintenance tasks. Benching, low flow pipes and channels, drop structures, or similar measures should be utilized to convey low flow from the inlet to the principal outlet.

10.7. EMERGENCY OUTLETS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Clean**
- **Erosion and Scour**
- **Excessive Sedimentation**
- **Displaced Lining**

1. Grass and other vegetative cover is encouraged whenever flow velocities, soil stability, and other design constraints permit. Surface and subsurface soil stabilization measures should be used to increase allowable flow velocities and to reduce erosion and scour. [**Note**: Safe passage of emergency overflows and emergency spillway stability must, however, receive first priority and must not be compromised by selection of emergency outlet lining.]

2. Where nonvegetative linings are required (see 1 above), loose stone, riprap, and other irregular linings which require hand removal of trash, debris, and undesirable vegetation should be avoided.

3. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

4. See **B. DAMS, EMBANKMENTS, AND SIDE SLOPES** for information regarding emergency outlet side slopes.

10.8. LOW FLOW MEASURES - DRY AND EXTENDED DRY FACILITIES

Since low flow measures are typically one of the first facility components to receive sediment, trash, and debris from incoming runoff, they usually require a high degree of maintenance Typical problems that impede or unnecessarily increase proper maintenance include:

- **Erosion and Scour**
- **Difficult to Clean or Mow**
- **Settlement**
- **Excessive Sedimentation**

However, while attempting to minimize low flow channel maintenance, care should be taken to avoid reducing the system's pollutant removal capabilities.

1. To ensure thorough drying of the facility bottom, low flow channels should have sufficient capacity to convey the normal, dry weather discharges from the facility inlets to the principal outlet structure without overtopping. The resultant channel size should also consider the use of readily available lining materials or construction equipment.

2. Design velocities in low flow channels should be low enough to prevent erosion of linings.

3. To simplify mowing and minimize trimming, grass-lined low flow channels are recommended whenever non-erosive velocities, smooth alignment, and thorough drying between storm events can be achieved.

4. Where low flow channels with nonvegetative lining are required, the use of gabions, concrete, grouted riprap, or other durable material with a relatively smooth surface is recommended to facilitate trash and debris removal and simplify mowing and trimming of adjacent grassed areas. Avoid the use of loose stone, riprap, and other materials with irregular surfaces which require hand removal of trash, debris, and undesirable vegetation.

In addition, use of low flow channels must be balanced with the need for pollutant removal in the facility. Therefore, low flow channels lined with nonvegetated lining should be used in conjunction with pretreatment BMPs such as inlet forebays and/or outlet structure wetlands, or the channel's should include portions with vegetated linings.

5. Low flow channel underdrains connected to the principal outlet structure or other stable downstream discharge point are recom-

Sediment and debris can be removed more easily from low flow channels lined with concrete or other smooth, durable material.

mended to promote quick, thorough drying of both the low flow channel and facility bottom.

6. To prevent erosion and scour, bank full velocities in low flow channels lined with nonvegetative lining should not exceed the maximum permissible velocity in adjacent grassed or vegetated areas. If non-erosive velocities cannot be achieved, the lining should be extended into the adjacent areas. When checking the bank-full velocities, the effects of submergence by the principal outlet structure during passage of the bank-full flow must be considered.

7. To ensure thorough drying of adjacent grassed areas, low flow channels lined with concrete, grouted riprap, and other rigid, impervious material should be designed with the top of the lining at or below the elevation of adjacent grassed areas. This will also assist mowing and trimming. To achieve this, consideration should be given to the potential for settlement of both the impervious lining and adjacent areas and the effects of frost action on the lining. Broken stone foundations and weep holes should be provided for all impervious lining. (See No. 8 below) In addition, the required depth and width of the low flow channel must be remembered when preparing the bottom grading plan.

8. Four inch diameter weep holes should be provided in all rigid, impervious linings to reduce hydrostatic pressure resulting from fluctuating groundwater levels. These weep holes should be spaced a maximum of 12 feet on center or one for every 100 square feet of lining, whichever is less. Weep holes must not be directly connected to any low flow channel underdrain pipe. Place geotextile filter fabric under weepholes.

9. In subsurface facilities, dry weather inflow should not interfere with routine inspection and maintenance. Benching, underdrains, drop inlets, and other measures should be utilized.

10.9. VEGETATIVE COVER

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Excessive Sedimentation**
- **Erosion and Scour**
- **Difficult to Mow**
- **Poor Growth (traffic, compaction)**

1. To minimize maintenance efforts, the use of existing, undisturbed site vegetation is encouraged. To do so, the existing site topography must provide adequate storage volume. Where disturbance of existing vegetation cannot be avoided, replacement with low maintenance, preferable native, vegetation with strong resistance to disease and allelopathic (self-weeding) characteristics is encouraged.

In general and where appropriate, turf grass may be easier to establish and maintain than other types of ground cover vegetation. However, pollutant removal efficiency will generally be reduced. The use of native grass varieties that are relatively slow growing and tolerant of poor soil conditions, crown vetch in the East, will minimize routine maintenance tasks such as mowing and fertilizing.

The need for supplemental fertilizing can be substantially reduced when the vegetative cover includes a percentage of nitrogen-fixing species, such as white clover and other legumes. In addition to minimizing maintenance costs, a reduction in required fertilization will also minimize the potential pollution effects of nutrients such as nitrogen and phosphorus in the outflow.

3. To promote lasting growth, grasses and other vegetative covers should be compatible with the prevailing weather and soil conditions and tolerant of periodic inundation and runoff pollutants.

4. To promote lasting growth, an adequate

depth of suitable topsoil should be provided below all vegetative covers. A minimum thickness of 4-6 inches is recommended for turf grasses.

5. Construction plans and specifications should include requirements for establishing all vegetative covers including requirements for reseeding or resodding as necessary.

6. At dry and extended dry detention systems, the effects of sediment removal from vegetated surfaces should be considered in the selection of appropriate cover.

7. Additional information on vegetative covers is available from such agencies as the Natural Resource Conservation Service, local Soil Conservation Districts, and County Cooperative Extension Service offices. Consultation with these agencies during facility planning, design, and review is encouraged.

10.10. TRASH RACKS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Clean**
- **Difficult to Remove**
- **Structural Failure**
- **Excessive Debris**

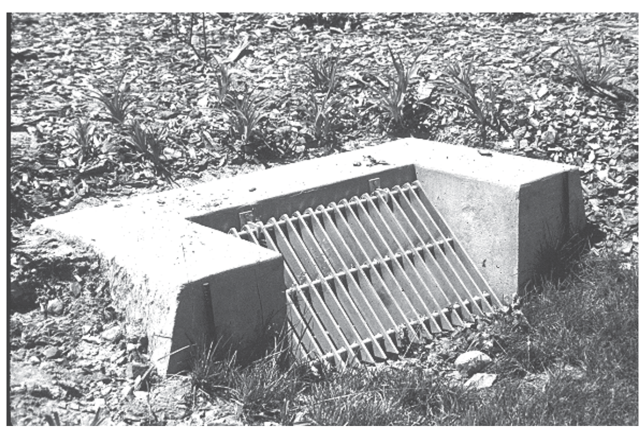
1. Trash racks are intended to prevent trash and debris from blocking a facility outlet by intercepting it at an upstream point. Therefore, the need for a trash rack should be based upon the relative sizes and shapes of both the outlet opening and the anticipated debris as well as the consequences of outlet clogging. Special consideration should be given to subsurface facilities.

2. For durability, all track rack components, including bars, hinges, fasteners, and clamps, should be constructed of lightweight, noncorroding material such as aluminum. The components should have sufficient design strength to withstand anticipated heavy loads caused by facility outflows, debris, and, where necessary, maintenance personnel.

3. To facilitate cleaning, trash racks should be comprised primarily of sloping bars, aligned longitudinally (in the direction of flow). Perpendicular bars, aligned transverse to the direction of flow, should be added for strength and rigidity. These transverse bars should be located below the top face of the longitudinal bars and, if possible, should be round in section. See Figure 3-B at the rear of the chapter for details.

4. To minimize the frequency of cleaning, trash rack bars should be spaced close enough to collect debris which may block the outlet orifice or weir but allow passage of smaller debris which will not. In general, longitudinal bars should be spaced a distance equal to 1/3 to 1/2 the diameter of the outlet orifice or 1/3 or 1/2 the width or height (whichever is less) of the outlet weir. Minimum and maximum spacings of 1 inch and 6 inches on center, respectively, are recommended. Transverse bars should be spaced as necessary for strength and rigidity. See Figure 3-B for details.

Sloping trash rack bars aligned in the direction of flow are more easily cleaned. Add transverse bars as needed for stability.



5. Trash racks should be sloped and hinged or attached with noncorroding, removable fasteners to allow access to the outlet orifice or weir by maintenance personnel. Lightweight trash racks are easier to lift, repair, and clean behind. See Figure 3-B for details.

Hinged, lightweight trash racks can be quickly lifted for cleaning and inspection. Also note outlet orifice plate mounted to outlet structure wall with removable anchor bolts.

6. Trash racks should be accessible for cleaning when the system is dry (at dry and extended dry facilities) or at normal or permanent pool levels (at wet facilities). In addition, access should also be provided when the water level is at the facility's maximum design water surface elevation. Stable areas of adequate size should be provided around a trash rack to provide firm footing for maintenance personnel and equipment. Concrete pads of other firm surfaces are recommended.

7. At wet detention systems, stable areas of adequate size should be provided at all trash racks which protect permanent pool drains. Concrete pads or other firm surface is recommended.

10.11. ACCESS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Inadequate or Unsafe Access to Facility Components**
- **Heavy or Inoperable Gratings and Hatches**
- **Multiple or Corroded Locks**
- **Lack of Fence Gates**

1. The stormwater facility must be readily accessible from a street or other public right-of-way. Inspection and maintenance easements, connected to the street or right-of-way, should also be provided around the entire facility. The exact limits of the easements and right-of-way should be specified on the project plans and other appropriate property and legal documents.

2. Field evaluations indicate that readily visible detention systems receive more and better maintenance than those in less visible, more remote locations. This finding should be kept in mind during overall site layout. Readily visible facilities can also be inspected faster and more easily by maintenance and mosquito control personnel.

3. Access roads and gates should be wide enough to allow passage of necessary maintenance vehicles and equipment, including trucks, backhoes, grass mowers, and mosquito control equipment. In general, a minimum right-of-way width of 15 feet and a minimum roadway width of 12 feet is recommended. Access gates should be sited to allow vehicles to park off road for gate opening.

4. To facilitate entry, a curb cut should be provided where an access road meets a curbed roadway.

5. To allow safe movement of maintenance vehicles, access ramps should be provided to the bottoms of all detention systems greater that 5 feet in depth. Vehicle access ramps should not exceed 10 percent in grade.

6. Access roads and ramps should be stable and suitably lined to prevent rutting and other damage by maintenance vehicles and equipment.

7. When backing-up is difficult or dangerous, turnaround areas should be provided at the end of all access roads.

8. To expedite overall maintenance efforts, vehicle and equipment staging areas should be provided at or near each facility site.

9. A suitable number of gates should be provided in all fences. The gates should be wide enough to allow passage of necessary equipment and personnel. They should be appropriately located so that they can be fully opened without interference by trees, parked cars, existing or proposed grades, or other obstructions. If it is necessary to lock a gate, it should be done with a noncorroding chain and padlock. This will permit the installation of additional padlocks on the chain (each padlock becomes a link in the chain), thereby allowing authorized access through the gate by more than one person without the need for multiple keys.

10. Safe, suitable access for maintenance personnel and equipment should be provided to the exterior of each facility component. In doing so, avoid remote component locations, steep slopes, unstable surfaces and linings, and narrow walkways.

11. Suitable access should be provided along both sides of a fence for mowing, trimming, and fence repair.

12. Safe, suitable access for maintenance personnel and equipment should be provided to the interior of the principal outlet. In doing so, avoid heavy hatches, gratings, and other covers. Railings, grab rails, slip-resistant steps, low flow channels, benchings, and hinged, lightweight access covers greatly facilitate interior maintenance. Sufficient interior space should also be provided. A minimum horizontal dimension of 4 feet is recommended.

Successful facility maintenance demands adequate access for personnel and equipment. Note both wide access gate and concrete curbing that keeps it accessible.

13. At subsurface detention systems, suitable access, observation points, and monitoring wells should be provided to allow inspection and cleaning. Access should be provided to all major components, particularly at inlets and the principal and emergency outlets, and wherever sediment deposits are expected. This will permit sediment and debris removal through high pressure water spray and vacuum (e.g., Jet-Vac). All access points should be at safe locations on the surface which can be readily accessed, safely barricaded, and clearly identified.

Confined space entry considerations must be considered including:

- **proper ventilation**
- **adequate opening for full protection devices, etc.**

10.12. PERIMETERS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Mow**
- **Inadequate Size**
- **Too Close To Adjacent Structures**

1. Field evaluations indicate that readily visible detention systems receive more and better maintenance than those in less visible, more remote locations. This finding should be kept in mind during overall site layout. Readily visible facilities can also be inspected faster and more easily by maintenance and mosquito control personnel.

2. Fences, when required for safety or other purposes, should be located to minimize interference with grass mowing and trimming. Suitable access should be provided along both sides.

3. To allow safe movement of maintenance personnel; and equipment, fences should be located at least 3 feet beyond the top and toe of any slope steeper than 5 horizontal to 1 vertical.

4. Fences should be constructed of durable, vandal-resistant materials. Fences must meet all local code requirements.

5. To minimize the amount of required trimming, fences in grassed areas should be installed, whenever practical, with a bottom rail set high enough above finished grade to allow mowing beneath it.

6. Grassed areas beyond the tops of detention systems should have a minimum slope of 2 percent to promote effective surface drainage and thorough drying.

7. Perimeters should be planned and designed to discourage vandalism and dumping of trash and debris.

8. Facility perimeters should be large enough to allow movement and operation of maintenance and mosquito control equipment. A minimum perimeter width of 25 feet between the facility and adjacent structures is recommended along at least one side of the facility. This portion of the perimeter should be readily accessible from a street or other public right-of-way.

Lack of access prevents maintenance.

11. DESIGN GUIDELINES FOR INFILTRATION PRACTICES

11.1. INTRODUCTION

The following technical design guidelines are intended to help planners, designers, and reviewers produce stormwater infiltration facilities that require minimum levels of maintenance. Typical infiltration practices include:

- **Infiltration Basins**
- **Infiltration Swales**
- **Infiltration Trench**
- **Drywells**
- **Seepage Pits**

To help accomplish this minimum maintenance goal, the design guidelines have been developed to:

1. **Eliminate avoidable maintenance inspections, tasks, and problems.**

2. **Minimize the long term amount of regular facility maintenance.**

3. **Facilitate required maintenance inspection and tasks.**

4. **Reduce the potential for extensive, expensive, and often difficult remedial or emergency maintenance efforts.**

It is important to note that ***these design guidelines are intended to supplement all other applicable facility design standards and requirements, including those pertaining to a facility's hydrologic, hydraulic, structural, geotechnical, environmental, legal, and aesthetic aspects. As such, they should be used creatively with all other applicable standards and requirements to produce stormwater infiltration facilities that require optimum levels of maintenance performed with the least practical effort, time, and expense***. Those involved with the planning, design, and review of specific stormwater management systems must assume their share of the responsibility for a system's performance, longevity, and safety.

To assist in their use, the technical design guidelines are presented separately for each major facility component as listed in Table 3-1. Complete descriptions of each type of infiltration practice is presented in Chapter 2.

Descriptions of typical maintenance problems encountered at each facility component are also described. These descriptions, which have been based upon facility inspections and interviews with maintenance personnel, highlight the types of maintenance problems that the design guidelines are intended to prevent or minimize. They should serve to further stimulate planners, designers, and reviewers to develop additional, improved, and/or site-specific designs.

11.2. BOTTOMS

In a study performed by the N.J. Department of Environmental Protection, the bottoms of infiltration basins and swales were the most likely location of chronic maintenance problems. Typical problems that impede or unnecessarily increase proper maintenance include:

- **Standing Water**
- **Soggy Surfaces**
- **Poor Grass Growth**
- **Excessive Sedimentation**
- **Limited Access**

1. The infiltration rate of the soil will determine a site's suitability as an infiltration system. In general, infiltration practices should only be constructed in areas of Hydrologic Soil

Group A or B as defined by the Natural Resource Conservation Service. Borings, test pits, and other appropriate field tests should be taken of the system's surface and subsurface soils. In subsurface facilities (e.g., dry wells, seepage pits, infiltration trenches) which are enveloped by geotextile or filter fabric, the limiting infiltration rate of the facility may be dictated by the fabric instead of the surrounding soil. See **Chapter 2** for additional recommendations regarding the selection of appropriate design infiltration rates for different types of infiltration practices.

2. To provide adequate drying time, to avoid delaying scheduled maintenance efforts, to avoid anaerobic conditions, and to prevent mosquito breeding, the maximum storage or ponding duration should not exceed 24-48 hours, depending on the tolerance of the system's vegetation to wetness.

3. To promote complete infiltration and prevent standing water or soggy surfaces, the lowest point in the bottom of the facility should be at least 4 feet above the seasonally high ground water level or bedrock. Subsurface drains may be used to lower ground water levels and/or promote complete infiltration. (See No. 4 below.) In determining the seasonally high ground water level, the extent of potential local ground water mounding due to the infiltration of stormwater from the facility must be evaluated.

4. To promote complete infiltration and prevent standing water or soggy surfaces, bottoms should have a minimum slope of 1 percent directed towards the center or other area of the facility bottom. It is recommended that bottoms be vegetated as the roots help to maintain soil permeability and the vegetation helps to minimize the potential for ground water contamination. A gabion-lined or stone-filled trench can be used to help promote infiltration. This trench should be located at the lowest point in the bottom and extend to all inlet points in order to direct small or dry weather inflows to the basin bottom. The elevation of the trench bottom should be at least 4 feet above the seasonally high ground water level or bedrock. See Figure 3-C at the rear of the chapter for details.

5. To avoid delaying scheduled maintenance efforts, topsoils should be sufficiently permeable to allow thorough drying through evaporation and moisture uptake by vegetative covers.

6. In order to prevent sloughing caused by outflow seepage of infiltrated water, an infiltration system should not be located on or near a steep slope. In general, a facility should not be constructed where nearby slopes exceed 15 percent. Appropriate geotechnical analyses should be conducted when necessary.

7. Sediment from construction operations can quickly clog soil pores of an infiltration system, often necessitating expensive maintenance work even before the facility is placed into normal operation. Therefore, an infiltration system should not be used for sediment control purposes during construction and, consequently, should not be constructed until the upstream drainage area is fully developed and adequately stabilized. If that is not feasible, the facility should not be excavated to it's full depth until all disturbed areas have been stabilized or protected. Thereafter, final excavation to finished grade should also include removal of all deposited sediment. Under no circumstances should a subsurface infiltration facility (e.g., drywell, seepage pit, infiltration trench, etc.) be used for sediment control during construction.

8. During construction, heavy equipment should not be allowed on the facility bottom. Compaction of the natural subgrade can seriously impair the infiltration rate.

9. As an alternative cover, a 12 inch layer of filter material, such as coarse sand, may be considered in the facility bottom. This layer of material can be cleaned of sediment or replaced as necessary. Prior to the selection of this alternative material, such factors as aesthetics, weed growth, and movement of maintenance personnel and equipment about the bottom must be considered. See Figure 3-D at the rear of the chapter for details.

10. To minimize routine grass maintenance such as mowing and fertilizing, the use of native grass varieties that are relatively slow growing and tolerant of poor soil conditions are encouraged. Information on these and other grass varieties and mixtures are available from the local Cooperative Extension Service or Soil Conservation District. (See **E. VEGETATIVE COVER** for additional details.)

11. To promote lasting growth, grasses and other vegetative covers should be compatible with the prevailing weather and soil conditions and tolerant of periodic inundation and harmful runoff pollutants. (See **E. VEGETATIVE COVER** for additional details.)

12. To facilitate removal efforts, sedimentation should be promoted at localized, readily accessible areas. Swale conveyances and sediment traps or forebays at inflow and outflow points should be used. Those lined completely or partially with smooth materials such as reinforced concrete can be more readily cleaned. For these reasons, the exclusive use of loose stone, riprap, and other irregular linings which require manual removal of weeds, sediment, and debris should be avoided wherever possible.

Forebays trap sediment and debris before it enters the facility in areas that can be more readily cleaned.

13. Suitable access for maintenance personnel and equipment should be provided to the facility bottom. (See **F. ACCESS** for details.)

Access to all areas of the facility by both personnel and equipment is vital to successful maintenance.

14. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

15. Temporary emergency measures such as pumps should be provided to drain standing water from malfunctioning infiltration practices.

16. If feasible, alternative outlet measures should be designed to permanently convert an infiltration system to a detention facility if necessary due to loss of infiltration capacity. If practical, these alternative outlet measures should be included in the facility's original construction.

17. At subsurface infiltration facilities, suitable access, observation points, and/or moni-

toring wells, should be provided to facilitate inspection and cleaning. (See **F. ACCESS** for additional details.)

18. Wherever possible, sediment disposal and storage areas should be provided adjacent to the facility. These areas should optimally be designed to contain 2 years or more of removed sediment.

11.3. DAMS, EMBANKMENTS, AND SIDE SLOPES

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Steep Slopes**
- **Long Slopes**
- **Poor Grass Growth**
- **Sloughing and Erosion**

1. For safe movement of maintenance personnel and safe operation of equipment, side slopes greater than 5 feet in height should not be steeper than 4 horizontal to 1 vertical. Side slopes less than 5 feet high should not exceed 3 horizontal to 1 vertical. Flatter side slopes are recommended wherever possible.

2. For safe movement of maintenance personnel and safe operation of equipment, side slopes steeper than 5 to 1 and higher than 15 feet should be terraced at their midpoints. The terrace should have a minimum width of 3 feet and should be graded at 2 percent towards the lower half of the slope.

3. Suitable access to and along side slopes should be provided for maintenance personnel and equipment. (See **F. ACCESS** for details.)

4. Topsoil and vegetative covers must be protected from erosion caused by local runoff and the slope's steepness. Surface and subsurface soil stabilization measures or nonvegetated linings should be used as necessary. In doing so, avoid the use of loose stones, riprap, and other irregular lining materials which require hand removal of weeds and debris and may be a hazard to maintenance personnel walking on the slope.

5. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges. The use of herbicides is discouraged unless done by trained applicators.

6. The effects of rapid pool drawdown should be checked to prevent side slope sloughing.

7. For safe movement of maintenance personnel and safe operation of equipment, fences should not be constructed within 3 feet of either the top or toe of any side slope that exceeds 5 horizontal to 1 vertical.

Adequate distance should be provided between the top of a slope and adjacent structures such as fences, walls, curbs, or roadways.

11.4. INLETS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Clean**
- **Erosion and Scour**
- **Excessive Sedimentation**
- **Displaced Lining**

1. The number of inlets to an infiltration system should be kept to a minimum. This will minimize the amount of required downstream lining, forebays, and low flow channels. All inflow pipes and culverts should terminate at a headwall or flared end section with adequate cutoff walls. Inlets should be located to prevent or minimize flow short-circuiting. However, short circuiting is not an issue if the device is fully retentive. It is an issue if it is a retention/detention situation.

Facility inlets must terminate with a headwall or flared end section to prevent scour and provide stability.

2. Linings placed downstream of facility inlets should accommodate design flows without erosion or scour. They should also facilitate removal of sediment, trash, debris, and undesirable vegetation.

3. Forebays and other localized sediment and debris traps should be placed immediately downstream of facility inlets. Where practical, avoid loose stone, riprap, and other irregularly shaped linings which require hand removal sediment, trash, and debris. (See **A. BOTTOMS** for additional details.)

4. The BMP Treatment Train approach should be used to minimize sediment entering the facility should be considered. Street sweeping, offsite soil stabilization measures, and upsteam sedimentation basins, swales, and other source control BMPs can significantly reduce the frequency of required sediment and trash removal operations.

5. To facilitate cleaning, inflow pipes should be a minimum diameter of 15 inches. The pipes should be constructed of durable materials, such as reinforced concrete.

6. Grading and landscaping around facility inlets should be designed to facilitate mowing, trimming, debris removal, and other general maintenance tasks. Grassed slopes which require mowing should not exceed 3 horizontal to 1 vertical. Vegetated cover which does not require mowing or nonvegetated linings should be used where steeper slopes are necessary.

7. Stable areas which provide maintenance personnel with firm footing should be provided at facility inlets. Linings such as reinforced concrete and gabions should be considered.

8. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

9. Dry weather flow from a facility inlet should not interfere with routine maintenance tasks. Benching, low flow pipes and channels, drop structures, or similar measures should be utilized to convey low flow from the inlet to the principal outlet.

11.5. EMERGENCY OUTLETS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Clean**
- **Erosion and Scour**
- **Excessive Sedimentation**
- **Displaced Lining**

1. Grass and other vegetative cover is encouraged whenever flow velocities, soil stability, and other design constraints permit. Surface and subsurface soil stabilization measures should be used to increase allowable flow velocities and to reduce erosion and scour. [**Note**: Safe passage of emergency overflows and emergency spillway stability must, however, receive first priority and must not be compromised by selection of emergency outlet lining.]

2. Where nonvegetative linings are required (see 1 above), loose stone, riprap, and other irregular linings which require hand removal of trash, debris, and undesirable vegetation should be avoided.

3. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

4. See **B. DAMS, EMBANKMENTS, AND SIDE SLOPES** for information regarding emergency outlet side slopes.

11.6. VEGETATIVE COVER

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Excessive Sedimentation**
- **Erosion and Scour**
- **Difficult to Mow**
- **Poor Growth**

1. To minimize maintenance efforts, the use of existing, undisturbed site vegetation is encouraged. To do so, the existing site topography must provide adequate storage volume. Where disturbance of existing vegetation cannot be avoided, replacement with low maintenance, preferably native, vegetation with strong resistance to disease and allelopathic (self-weeding) characteristics is encouraged. In general and where appropriate, turf grass may be easier to establish and maintain than other types of ground cover vegetation. The use of grass varieties that are relatively slow growing and tolerant of poor soil conditions will minimize routine maintenance tasks such as mowing and fertilizing.

The need for supplemental fertilizing can be substantially reduced when the vegetative cover includes a percentage of nitrogen-fixing species, such as white clover and other legumes. In addition to minimizing maintenance costs, a reduction in required fertilization will also minimize the potential pollution effects of nutrients such as nitrogen and phosphorus in the outflow.

3. To promote lasting growth, grasses and other vegetative covers should be compatible with the prevailing weather and soil conditions and tolerant of periodic inundation and runoff pollutants.

4. To promote lasting growth, an adequate depth of suitable topsoil should be provided below all vegetative covers. A minimum thickness of 6 inches is recommended for turf grasses.

5. Construction plans and specifications should include requirements for establishing all vegetative covers.

6. The effects of sediment removal from vegetated surfaces should be considered in the selection of appropriate cover.

7. Additional information on vegetative covers is available from such agencies as the Natural Resource Conservation Service, local Soil Conservation Districts, and County Cooperative Extension Service offices. Consultation with these agencies during facility planning, design, and review is encouraged.

11.7. ACCESS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Inadequate or Unsafe Access to Facility Components**
- **Heavy or Inoperable Gratings and Hatches**
- **Multiple or Corroded Locks**
- **Lack of Fence Gates**

1. The facility must be readily accessible from a street or other public right-of-way. Inspection and maintenance easements, connected to the street or right-of-way, should also be provided around the entire facility. The exact limits of the easements and right-of-way should be specified on the project plans and other appropriate property and legal documents and be of sufficient size to handle maintenance equipment.

2. Field evaluations indicate that readily visible infiltration practices receive more and better maintenance than those in less visible, more remote locations. This is especially true for infiltration systems that are integrated into a site's overall landscaping plan or where they are used for recreation. These findings should be kept in mind during overall site layout. Readily visible facilities can also be inspected faster and more easily by maintenance and mosquito control personnel.

3. Access roads and gates should be wide enough to allow passage of necessary maintenance vehicles and equipment, including trucks, backhoes, grass mowers, and mosquito control equipment. In general, a minimum right-of-way width of 15 feet and a minimum roadway width of 12 week is recommended.

4. To facilitate entry, a curb cut should be provided where an access road meets a curbed roadway.

5. To allow safe movement of maintenance vehicles, access ramps should be provided to the bottoms of all infiltration facilities greater that 5 feet in depth. Vehicle access ramps should not exceed 10 percent in grade.

6. Access roads and ramps should be stable and suitably lined to prevent rutting and other damage by maintenance vehicles and equipment.

7. When backing-up is difficult or dangerous, turnaround areas should be provided at the end of all access roads.

8. To expedite overall maintenance efforts, vehicle and equipment staging areas should be provided at or near each facility site.

9. A suitable number of gates should be provided in all fences. The gates should be wide enough to allow passage of necessary equipment and personnel. They should be appropriately located so that they can be fully opened without interference by trees, parked cars, existing or proposed grades, or other obstructions. If it is necessary to lock a gate, it should be done with a noncorroding chain and padlock. This will permit the installation of additional padlocks on the chain (each padlock becomes a link in the chain), thereby allowing authorized access through the gate by

Successful facility maintenance demands adequate access for personnel and equipment. Note wide access gate and concrete curbing that keeps it accessible.

more than one person without the need for multiple keys.

10. Safe, suitable access for maintenance personnel and equipment should be provided to the exterior of each facility components. In doing so, avoid remote component locations, steep slopes, unstable surfaces and linings, and narrow walkways.

11. Suitable access should be provided along both sides of a fence for mowing, trimming, and fence repair.

12. At subsurface infiltration facilities, suitable access, observation points, and monitoring wells should be provided to allow inspection and cleaning. Access should be provided to all major components, particularly at inlets and emergency outlets, and wherever sediment deposits are expected. This will permit sediment and debris removal through high pressure water spray and vacuum (e.g., Jet-Vac). All access points should be at safe locations on the surface which can be readily accessed, safely barricaded, and clearly identified.

11.8. PERIMETERS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Mow**
- **Inadequate Size**
- **Too Close To Adjacent Structures**

1. Field evaluations indicate that readily visible and multipurpose infiltration practices receive more and better maintenance than those in less visible, more remote locations. This finding should be kept in mind during overall site layout. Readily visible facilities can also be inspected faster and more easily by maintenance and mosquito control personnel.

2. Fences, when required for safety or other purposes, should be located to minimize interference with grass mowing and trimming. Suitable access should be provided along both sides.

3. To allow safe movement of maintenance personnel and equipment, fences should be located at least 3 feet beyond the top and toe of any slope steeper than 5 horizontal to 1 vertical.

4. Fences should be constructed of durable, vandal-resistant materials. Fences must meet all local code requirements.

5. To minimize the amount of required trimming, fences in grassed areas should be installed, whenever practical, with a bottom rail set high enough above finished grade to allow mowing beneath it.

6. Grassed areas beyond the tops of infiltration systems should have a minimum slope of 2 percent to promote effective surface drainage and thorough drying.

7. Perimeters should be planned and designed to discourage vandalism and dumping of trash and debris.

8. Facility perimeters should be large enough to allow movement and operation of maintenance and mosquito control equipment. A minimum perimeter width of 25 feet between the facility and adjacent structures is recommended along at least one side of the facility. This portion of the perimeter should be readily accessible from a street or other public right-of-way.

12. DESIGN GUIDELINES FOR FILTRATION AND BIOFILTRATION PRACTICES

12.1 INTRODUCTION

The following technical design guidelines are intended to help planners, designers, and reviewers produce stormwater filtration and biofiltration facilities that require minimum levels of maintenance. Typical practices include:

- **Sand Filters**
- **Peat Filters**
- **Constructed Wetlands**
- **Wet and Dry Swales**
- **Vegetated Buffer Strips**

In should be noted that, in many instances, filtration and biofiltration practices are often used in combination with or as an integral part of other types of stormwater management facilities. For example, an extended dry detention basin may include a constructed wetland over all or portions of its bottom. In such cases, the reader should also refer to the design recommendations for those facilities presented in this chapter.

To help accomplish the minimum maintenance goal described above, the design guidelines have been developed to:

1. **Eliminate avoidable maintenance inspections, tasks, and problems.**

2. **Minimize the long term amount of regular facility maintenance.**

3. **Facilitate required maintenance inspection and tasks.**

4. **Reduce the potential for extensive, expensive, and often difficult remedial or emergency maintenance efforts.**

It is important to note that the design guidelines are intended to supplement all other applicable facility design standards and requirements, including those pertaining to a facility's hydrologic, hydraulic, structural, geotechnical, environmental, legal, and aesthetic aspects. As such, they should be used creatively with all other applicable standards and requirements to produce filtration and biofiltration systems that require optimum levels of maintenance performed with the least practical effort, time, and expense. Those involved with the planning, design, and review of specific stormwater management systems must assume their share of the responsibility for a system's performance, longevity, and safety.

To assist in their use, the technical design guidelines are presented separately for each major facility component as listed in Table 3-1. Complete descriptions of each type of facility or practice is presented in Chapter 2.

Descriptions of typical maintenance problems encountered at each facility component are also described. These descriptions, which have been based upon facility inspections and interviews with maintenance personnel, highlight the types of maintenance problems that the design guidelines are intended to prevent or minimize. They should serve to further stimulate planners, designers, and reviewers to develop additional, improved, and/or site-specific designs.

12.2. BOTTOMS

Due to their wide variability, the bottoms of filtration and biofiltration practices may range from the reinforced concrete bottom of a subsurface sand filter to a wetland to the grass in a filter or buffer strip. Therefore, the direct applicability of the design guidelines presented below will depend upon the type of filtration or biofiltration BMP under design. To assist in their use, the following design guidelines for bottoms will address both dry (e.g., filter strip) and wet (e.g., constructed wetlands) practices.

Typical problems that impede or unnecessarily increase proper facility maintenance include:

- **Standing Water (in Dry Systems)**
- **Soggy Surfaces (in Dry Systems)**
- **Lack of Permanent Pool (in Wet Systems)**
- **Poor Grass Growth**
- **Excessive Sedimentation**
- **Limited Access**

1. To promote complete emptying and prevent standing water or soggy surfaces in dry systems, vegetated bottoms should have adequate bottom slope and be graded to the outlet. In selecting a bottom, care must also be taken not to exceed the slopes required for adequate pollutant removal. If a reasonable compromise cannot be achieved, another type of stormwater management practice should be considered.

2. To promote complete emptying and prevent standing water or soggy surfaces in dry-type facilities, the lowest point in the bottom should be at least 4 feet above the seasonally high groundwater level or bedrock unless adequate subsurface drains are provided.

3. To provide adequate drying time in dry practices, to avoid anaerobic conditions, to avoid delaying scheduled maintenance efforts, and to prevent mosquito breeding, the maximum wet or ponding duration should not exceed 24-48 hours, depending on the tolerance of the vegetation to wetness.

4. To avoid delaying scheduled maintenance efforts in dry facilities, topsoils and subsurface soils should be sufficiently permeable to allow both rapid infiltration and evaporation.

5. In dry systems, subsurface drains connected to the principal outlet structure or other discharge point are encouraged to promote quick and thorough drying of the facility bottom. In doing so, care should be taken to prevent stormwater inflow from inadvertently bypassing the basin's outlet controls.

6. To minimize routine grass maintenance such as mowing and fertilizing in dry systems such as filter and buffer strips, the use of native grass varieties that are relatively slow growing and tolerant of poor soil conditions are encouraged. Information on grass varieties and mixtures are available from agencies such as the local Cooperative Extension Service or Soil Conservation District. (See **I. VEGETATIVE COVER** for additional details.)

7. To promote lasting growth in dry systems, grasses and other vegetative covers should be compatible with the prevailing weather and soil conditions and tolerant of periodic inundation and runoff pollutants. (See **I. VEGETATIVE COVER** for additional details.)

8. To facilitate removal efforts, sedimentation should be promoted at localized, readily accessible areas. Sediment traps or forebays at inflow and outflow points should always be used. Those lined completely or partially with smooth materials such as reinforced concrete

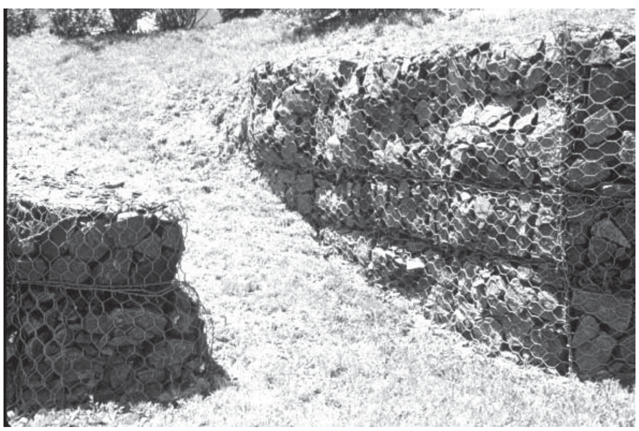
Forebays trap sediment and debris before it enters the facility in areas that can be more readily cleaned.

can be more readily cleaned. For these reasons, the exclusive use of loose stone, riprap, and other irregular linings which require manual removal of weeds, sediment, and debris should be avoided wherever possible.

9. Wherever possible, sediment disposal and storage areas should be provided adjacent to the facility. These areas should optimally be designed to contain 2 years or more of removed sediment.

10. Suitable access for maintenance personnel and equipment should be provided to the facility bottom. (See **I. ACCESS** for details.)

Access to all areas of the facility by both personnel and equipment is vital to successful maintenance.



11. Construction plans and specifications should include provisions that minimize the potential for localized settlement and subsequent ponding. These provisions include proper surface and subsurface soil characteristics, compaction requirements, grading equipment, and erosion control prior to the establishment or permanent vegetative cover.

12. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

13. At subsurface filtration facilities such as sand filters, suitable access, observation points, clean out ports, and/or monitoring wells should be provided to facilities inspection and cleaning. (See **I. ACCESS** for additional details.)

14. Design of a biofiltration facility such as a constructed wetland should include the determination of the proposed site's ability to adequately support a viable and desired ecosystem. The design should account for such factors as the required rate and quality of dry weather inflow, the quality of stormwater inflow, seasonal and longer term variations in the ground water table, and the effects of expected sediment and other pollutant loadings.

15. Provisions to drain the permanent pool of wet systems (or the standing water chambers of a subsurface sand filter) are necessary for maintenance and safety. A gravity drain is the preferred method. If this is not feasible, suitable pumps and both primary and backup power sources should be provided. All pumps and backup power sources should be reserved for facility use only.

16. To promote complete emptying of the permanent pool when necessary, the bottom should have an adequate slope graded to the outlet drain or pump intake.

12.3. DAMS, EMBANKMENTS, AND SIDE SLOPES

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Steep Slopes**
- **Long, Continuous Slopes**
- **Poor Grass Growth**
- **Sloughing and Erosion**

1. For safe movement of maintenance personnel and safe operation of equipment, side slopes greater that 5 feet in height should not be steeper than 4 horizontal to 1 vertical. Side

slopes less that 5 feet high should not exceed 3 horizontal to 1 vertical. Flatter side slopes are recommended wherever possible.

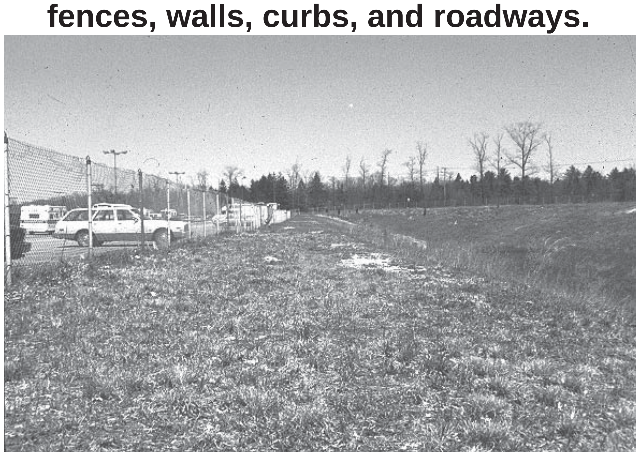
2. Suitable access to and along side slopes should be provided for maintenance personnel and equipment. (See **I. ACCESS** for details.)

3. Topsoil and vegetative covers must be protected from erosion caused by local runoff and the slope's steepness. Surface and subsurface soil stabilization measures or nonvegetated linings should be used as necessary. In doing so, avoid the use of loose stones, riprap, and other irregular lining materials which require hand removal of weeds and debris and may be a safety hazard to maintenance personnel walking along or up the slope.

4. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

5. For safe movement of maintenance personnel and safe operation of equipment, fenced should not be constructed within 3 feet of either the top or toe of any side slope that exceeds 5 horizontal to 1 vertical.

Adequate distance should be provided between the top of a slope and adjacent structures such as fences, walls, curbs, and roadways.



12.4. PRINCIPAL OUTLETS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Structural Deterioration**
- **Limited Access**
- **Corroded Appurtenances**
- **Vandalism**
- **Excessive Debris Accumulation**

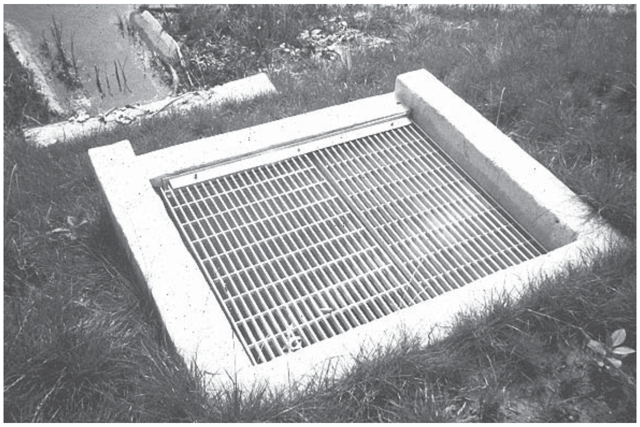
1. For durability, principal outlet structures should be constructed of reinforced concrete containing Type II cement and having a minimum specified 28-day compressive strength of 3,000 PSI. Concrete shall be designed in accordance with all applicable codes and requirements.

2. For durability, all appurtenances, including access hatches, trash racks, gratings, railings, orifice and weir plates, and fasteners should be constructed of lightweight, noncorroding materials. Material strengths should be sufficient to withstand design loads without damage or failure.

3. Outlet orifice and weir plates should be constructed from aluminum or other lightweight, noncorroding material. The plates should be fastened to the structure with noncorroding, removable fasteners. A gasket of neoprene or similar material should be placed between the plate and the structure wall. The opening in the structure wall over which the plate is bolted should have at least twice the area of the outlet orifice or weir to facilitate field adjustments and future expansion. See Figure 3-A at the rear of the chapter for details.

4. To facilitate access and movement by maintenance personnel, principal outlet structures should have a minimum horizontal interior dimension of 4 feet. (See **I. ACCESS** for additional details.)

Outlet structure gratings, trash racks, and other appurtenances should be lightweight, durable, and removable.



5. Vital parts of the principal outlet structure should be readily and safely accessible to maintenance personnel during both normal and emergency conditions. Temporary measures such as ladders are only acceptable for emergency conditions such as part of an approved emergency action plan. (See **I. ACCESS** for additional details.)

6. To minimize both required maintenance and the consequences of inadequate maintenance, principal outlets should avoid using moving or mechanized parts for outflow control whenever possible.

7. To facilitate cleaning, outlet pipes should have a minimum diameter of 15 inches. The pipes should be constructed of durable materials, such as reinforced concrete. To minimize potential leakage problems, the number of outlet pipe should be kept to an absolute minimum. More than one outlet pipe should be used only where unavoidable. All outlet pipes must be watertight under the maximum expected head or pressure.

8. Constructed wetlands and some filter systems often have a small orifices or a series of small orifices as part of the outlet structure. These are used to slowly bleed down the stormwater treatment volume. Innovative designs are needed to minimize their potential for clogging. Successful designs have included inverted siphons and half of a corrugated metal pipe, filled with large gravel, and placed in front of the orifices.

9. Grading and landscaping around principal outlet structures should be designed to facilitate mowing, trimming, debris removal, and other general maintenance tasks. Grassed slopes which require mowing should not exceed 3 horizontal to 1 vertical. Vegetated cover which does not require mowing or nonvegetated linings should be used where steeper slopes are necessary.

10. Stable areas that provide maintenance personnel with firm footing should be provided at the upstream face of principal outlet structures at dry and extended dry facilities. Linings such as reinforced concrete, gabions, and grouted riprap should be considered.

11. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

12. Dry weather flow through a principal outlet structure should not interfere with routine interior maintenance tasks. Benching, low flow pipes and channels, drop structures, or similar measures should be utilized to convey low flow into and through the structure.

13. Principal outlet structures should be designed to discourage vandalism and graffiti.

12.5. OUTFLOW SYSTEMS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Clean**
- **Erosion and Scour**
- **Excessive Sedimentation**
- **Displaced Lining**

1. The outflow conveyance system downstream of a filtration or biofiltration system should have adequate capacity to accommodate its outflows. This will not only allow design outflows and water surfaces to be attained, but will also help achieve required drawdown and emptying times.

2. Outflow velocities should be high enough to prevent sedimentation and low enough to prevent erosion and scour.

3. Manholes, grates and other suitable access points should be provided for cleaning and inspection. (See **I. ACCESS** for additional details.)

12.6. INLETS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Clean**
- **Erosion and Scour**
- **Excessive Sedimentation**
- **Displaced Lining**

1. The number of inlets to a filtration or biofiltration system should be kept to a minimum. This will minimize the amount of required downstream lining, forebays, and low flow channels. All inflow pipes and culverts should terminate at a headwall or flared end section with adequate cutoff walls. Inlets should be located to prevent or minimize flow short-circuiting.

2. Linings placed downstream of facility inlets should accommodate design flows without erosion or scour. Flow spreaders will help distribute flow at a shallow depth more uniformly over the facility bottom. They should also facilitate removal of sediment, trash, debris, and undesirable vegetation.

3. Forebays and other localized sediment and debris traps should be placed immediately downstream of facility inlets. Where practical, avoid loose stone, riprap, and other irregularly shaped linings which require hand removal sediment, trash, and debris. (See **A. BOTTOMS** for additional details.) Forebay outlets can also be used to distribute inflows more uniformly over the facility bottom.

Facility inlets must terminate with a headwall or flared end section to prevent scour and provide stability.

4. The BMP Treatment Train approach should be used to minimize sediment, trash, and other debris from entering the system. Street sweeping, offsite soil stabilization measures, and upsteam sedimentation basins, swales, and other source control BMPs can significantly reduce the frequency of required sediment or debris removal operations.

5. To facilitate cleaning, inflow pipes should be a minimum diameter of 15 inches. The pipes should be constructed of durable materials, such as reinforced concrete.

6. Grading and landscaping around facility inlets should be designed to facilitate mowing, trimming, debris removal, and other general maintenance tasks. Grassed slopes which require mowing should not exceed 3 horizontal to 1 vertical. Vegetated cover which does not require mowing or nonvegetated linings should be used where steeper slopes are necessary.

7. Stable areas which provide maintenance personnel with firm footing should be provided at facility inlets. Linings such as reinforced concrete and gabions should be considered.

8. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

9. Dry weather flow from a facility inlet should not interfere with routine maintenance tasks. Benching, low flow pipes and channels, drop structures, or similar measures should be utilized to convey low flow from the inlet to the principal outlet.

12.7. EMERGENCY OUTLETS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Clean**
- **Erosion and Scour**
- **Excessive Sedimentation**
- **Displaced Lining**

1. Grass and other vegetative cover is encouraged whenever flow velocities, soil stability, and other design constraints permit. Surface and subsurface soil stabilization measures should be used to increase allowable flow velocities and to reduce erosion and scour. [**Note**: Safe passage of emergency overflows and emergency spillway stability must, however, receive first priority and must not be compromised by selection of emergency outlet lining.]

2. Where nonvegetative linings are required (see 1 above), loose stone, riprap, and other irregular linings which require hand removal of trash, debris, and undesirable vegetation should be avoided.

3. All nonvegetative linings which are bordered by grass should be designed to permit complete mowing along all edges.

4. See **B. DAMS, EMBANKMENTS, AND SIDE SLOPES** for information regarding emergency outlet side slopes.

12.8. VEGETATIVE COVER

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Excessive Sedimentation**
- **Erosion and Scour**
- **Difficult to Mow**
- **Poor Growth (traffic, compaction)**
- **Invasion by undesirable species**

1. To minimize maintenance efforts, the use of existing, undisturbed site vegetation is encouraged. To do so, the existing site topography must provide adequate storage volume. Where disturbance of existing vegetation cannot be avoided, replacement with low maintenance vegetation with strong resistance to disease and allelopathic (self-weeding) characteristics is encouraged.

For dry swales and vegetated buffers, turf grass may be easier to establish and maintain than other types of ground cover vegetation. The use of native grass varieties that are relatively slow growing and tolerant of poor soil conditions will minimize routine maintenance tasks such as mowing and fertilizing. For constructed wetlands and wet swales, wetland aquatic plants are most appropriate. Specific recommendations regarding vegetation is presented in Chapter 2.

The need for supplemental fertilizing can be substantially reduced when the vegetative cover includes a percentage of nitrogen fixing species, such as white clover and other legumes. In addition to minimizing maintenance costs, a reduction in required fertilization will also minimize the potential pollution effects of nutrients such as nitrogen and phosphorus in the outflow.

3. To promote lasting growth, grasses and other vegetative covers should be compatible with the prevailing weather and soil conditions and tolerant of periodic inundation and runoff pollutants.

4. To promote lasting growth, an adequate depth of suitable topsoil or wetland muck soil should be provided below all vegetative covers. A minimum thickness of 6 inches is recommended for turf grasses.

5. Construction plans and specifications should include requirements for establishing all vegetative covers.

6. At both dry and wet systems, the effects of sediment removal from vegetated surfaces should be considered in the selection of appropriate cover.

7. Additional information on vegetative covers is available from such agencies as the Natural Resource Conservation Service, local Soil Conservation Districts, and County Cooperative Extension Service offices. Aquatic botanists should be consulted with respect to selecting and planting vegetation in constructed wetlands and wet swales. Consultation with these agencies or professionals during facility planning, design, and review is strongly encouraged.

12.9. TRASH RACKS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Clean**
- **Difficult to Remove**
- **Structural Failure**
- **Excessive Debris**

1. Trash racks are intended to prevent trash and debris from blocking a facility outlet by intercepting it at an upstream point. Therefore, the need for a trash rack should be based upon the relative sizes and shapes of both the outlet opening and the anticipated debris as well as the consequences of outlet clogging. Special consideration should be given to subsurface facilities.

2. For durability, all trash rack components, including bars, hinges, fasteners, and clamps, should be constructed of lightweight, noncorroding material such as aluminum. The components should have sufficient design strength to withstand anticipated heavy loads caused by facility outflows, debris, and, where necessary, maintenance personnel.

3. To facilitate cleaning, trash racks should be comprised primarily of sloping bars, aligned longitudinally (in the direction of flow). Perpendicular bars, aligned transverse to the direction of flow, should be added for strength and rigidity. These transverse bars should be located below the tope face of the longitudinal bars and, if possible, should be round in section. See Figure 3-B at the rear of the Chapter for details.

4. To minimize the frequency of cleaning, trash rack bars should be spaced close

Sloping trash rack bars aligned in the direction of flow are more easily cleaned. Add transverse bars as needed for stability.

enough to collect debris which may block the outlet orifice or weir but allow passage of smaller debris which will not. In general, longitudinal bars should be spaced a distance equal to 1/3 to 1/2 the diameter of the outlet orifice or 1/3 or 1/2 the width or height (whichever is less) of the outlet weir. Minimum and maximum spacings of 1 inch and 6 inches on center, respectively, are recommended. Transverse bars should be spaced as necessary for strength and rigidity. See Figure 3-B for details.

5. Trash racks should be hinged or attached with noncorroding, removable fasteners to allow access to the outlet orifice or weir by maintenance personnel. Lightweight track racks are easier to lift, repair, and clean behind. See Figure 3-B at the rear of the chapter for details.

Hinged, lightweight trash racks can be quickly lifted for cleaning and inspection. Also note outlet orifice plate mounted to outlet structure wall with removable anchor bolts.

6. Trash racks should be accessible for cleaning when the facility is dry (at dry facilities) or at normal or permanent pool levels (at wet facilities). In addition, access should also be provided when the water level is at the system's maximum design water surface elevation. Stable areas of adequate size should be provided around a trash rack to provide firm footing for maintenance personnel and equipment. Concrete pads of other firm surfaces are recommended.

7. At wet systems, stable areas of adequate size should be provided at all trash racks which protect permanent pool drains. Concrete pads or other firm surface is recommended.

12.10. ACCESS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Inadequate or Unsafe Access to Facility Components**
- **Heavy or Inoperable Gratings and Hatches**
- **Multiple or Corroded Locks**
- **Lack of Fence Gates**

1. The facility must be readily accessible from a street or other public right-of-way. Inspection and maintenance easements, connected to the street or right-of-way, should also be provided around the entire facility. The exact limits of the easements and right-of-way should be specified on the project plans and other appropriate property and legal documents.

2. Field evaluations indicate that readily visible or multipurpose systems receive more and better maintenance than those in less visible, more remote locations. This finding should be kept in mind during overall site layout. Readily visible facilities can also be inspected faster and more easily by maintenance and mosquito control personnel.

3. Access roads and gates should be wide enough to allow passage of necessary maintenance vehicles and equipment, including trucks, backhoes, grass mowers, and mosquito control equipment. In general, a mini-

mum right-of-way width of 15 feet and a minimum roadway width of 12 week is recommended.

4. To facilitate entry, a curb cut should be provided where an access road meets a curbed roadway.

5. To allow safe movement of maintenance vehicles, access ramps should be provided to the bottoms of all surface facilities greater that 5 feet in depth. Vehicle access ramps should not exceed 10 percent in grade.

6. Access roads and ramps should be stable and suitably lined to prevent rutting and other damage by maintenance vehicles and equipment.

7. When backing-up is difficult or dangerous, turnaround areas should be provided at the end of all access roads.

8. To expedite overall maintenance efforts, vehicle and equipment staging areas should be provided at or near each facility site.

9. A suitable number of gates should be provided in all fences. The gates should be wide enough to allow passage of necessary equipment and personnel. They should be appropriately located so that they can be fully opened without interference by trees, parked cars, existing or proposed grades, or other obstructions. If it is necessary to lock a gate, it should be done with a noncorroding chain and padlock. This will permit the installation of additional padlocks on the chain (each padlock becomes a link in the chain), thereby allowing authorized access through the gate by more than one person without the need for multiple keys.

10. Safe, suitable access for maintenance personnel and equipment should be provided to the exterior of each facility component. In doing so, avoid remote component locations,

Adequate distance should be provided between the top of a slope and adjacent structures such as fences, walls, curbs, and roadways.

steep slopes, unstable surfaces and linings, and narrow walkways.

11. Suitable access should be provided along both sides of a fence for mowing, trimming, and fence repair.

12. Safe, suitable access for maintenance personnel and equipment should be provided to the interior of the principal outlet. In doing so, avoid heavy hatches, gratings, and other covers. Railings, grab rails, slip-resistant steps, low flow channels, benchings, and hinged, lightweight access covers greatly facilitate interior maintenance. Sufficient interior space should also be provided. A minimum horizontal dimension of 4 feet is recommended.

13. At subsurface facilities, suitable access, observation points, and monitoring wells should be provided to allow inspection and cleaning. Access should be provided to all major components, particularly at inlets and the principal and emergency outlets, and wherever sediment deposits are expected. This will permit sediment and debris removal through high pressure water spray and vacuum (e.g., Jet-Vac). All access points should be at safe locations on the surface which can be readily accessed, safely barri-

caded, and clearly identified.

12.11. PERIMETERS

Typical problems that impede or unnecessarily increase proper maintenance include:

- **Difficult to Mow**
- **Inadequate Size**
- **Too Close To Adjacent Structures**

1. Field evaluations indicate that readily visible or multipurpose systems receive more and better maintenance than those in less visible, more remote locations. This finding should be kept in mind during overall site layout. Readily visible facilities can also be inspected faster and more easily by maintenance and mosquito control personnel.

2. Fences, when required for safety or other purposes, should be located to minimize interference with grass mowing and trimming. Suitable access should be provided along both sides.

3. To allow safe movement of maintenance personnel; and equipment, fences should be located at least 3 feet beyond the top and toe of any slope steeper than 5 horizontal to 1 vertical.

4. Fences should be constructed of durable, vandal-resistant materials. Fences must meet all local code requirements.

5. To minimize the amount of required trimming, fences in grassed areas should be installed, whenever practical, with a bottom rail set high enough above finished grade to allow mowing beneath it.

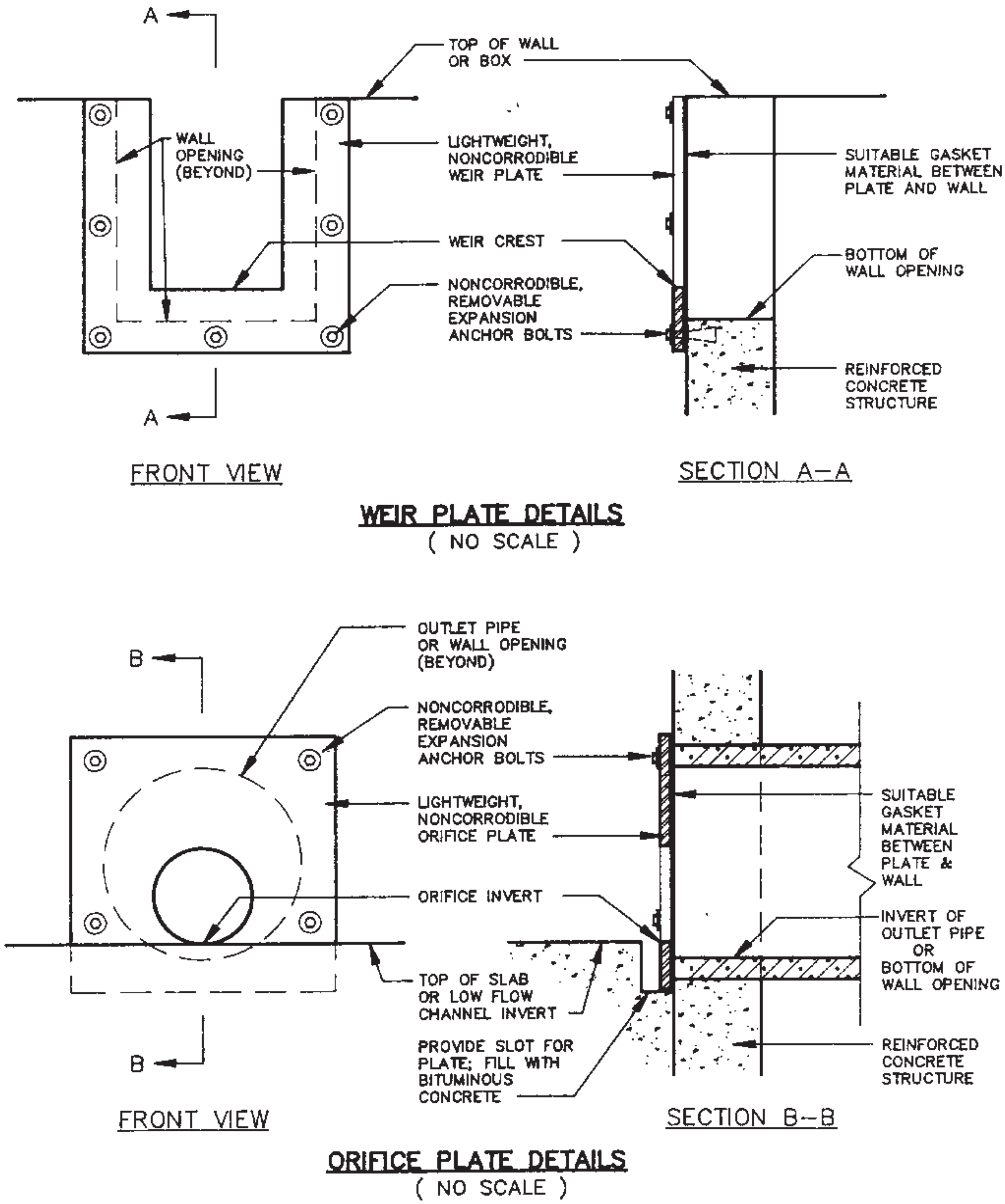
6. Grassed areas beyond the tops of filtration and biofiltration systems should have a minimum slope of 2 percent to promote effective surface drainage and thorough drying.

7. Perimeters should be planned and designed to discourage vandalism and dumping of trash and debris.

8. Facility perimeters should be large enough to allow movement and operation of maintenance and mosquito control equipment. A minimum perimeter width of 25 feet between the facility and adjacent structures is recommended along at least one side of the facility. This portion of the perimeter should be readily accessible from a street or other public right-of-way.

APPENDIX 3-1

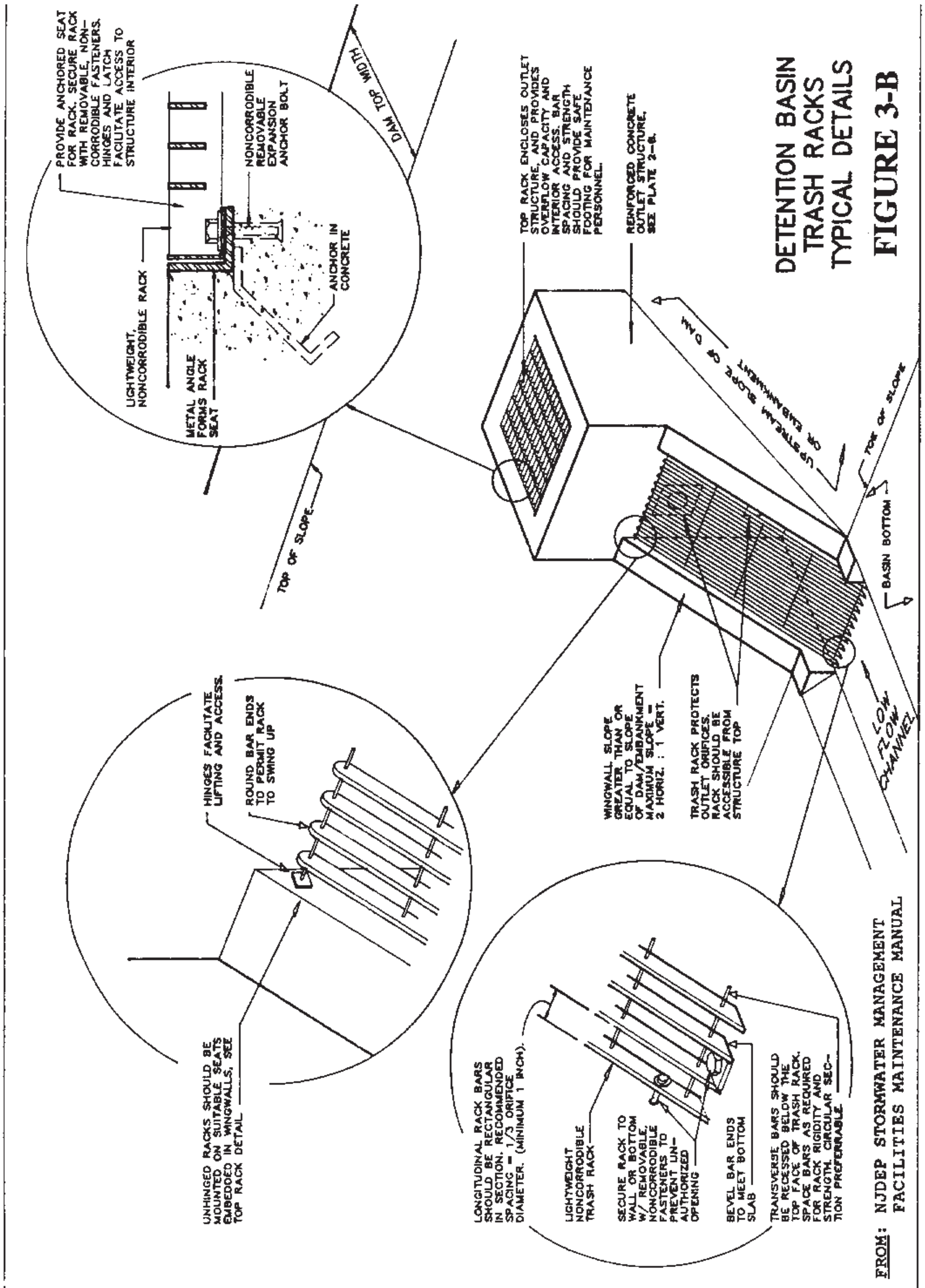
DRAWINGS OF TYPICAL DETAILS OF SOME IMPORTANT STORMWATER SYSTEM COMPONENTS



DETENTION BASIN
ORIFICE AND WEIR PLATES
TYPICAL DETAILS

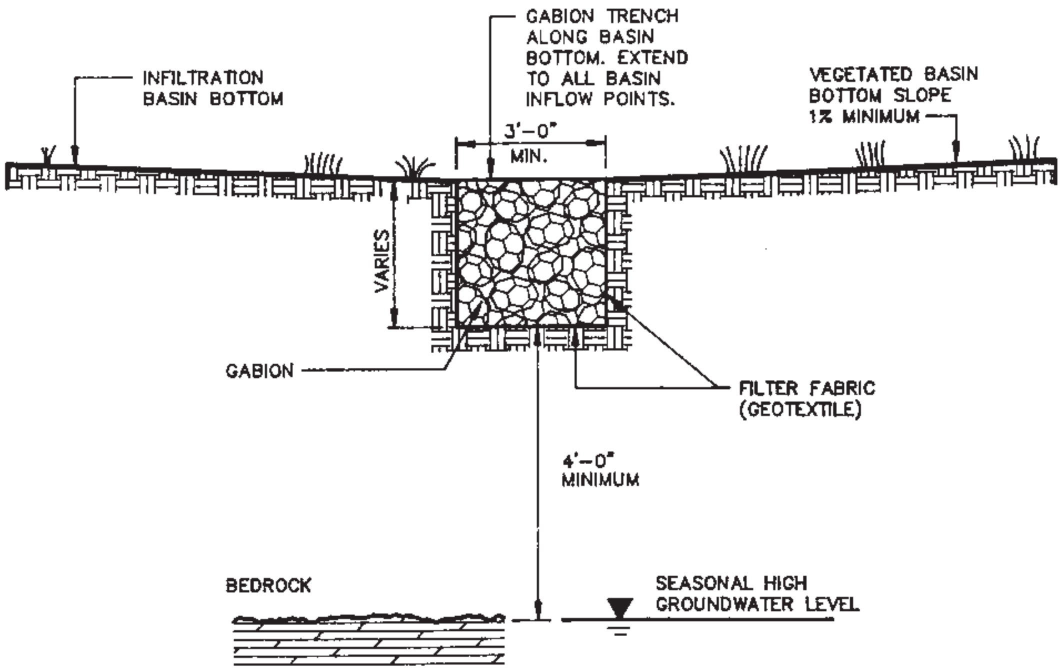
FIGURE 3-A

FROM: NJDEP STORMWATER MANAGEMENT FACILITIES MAINTENANCE MANUAL



DETENTION BASIN TRASH RACKS TYPICAL DETAILS

FIGURE 3-B



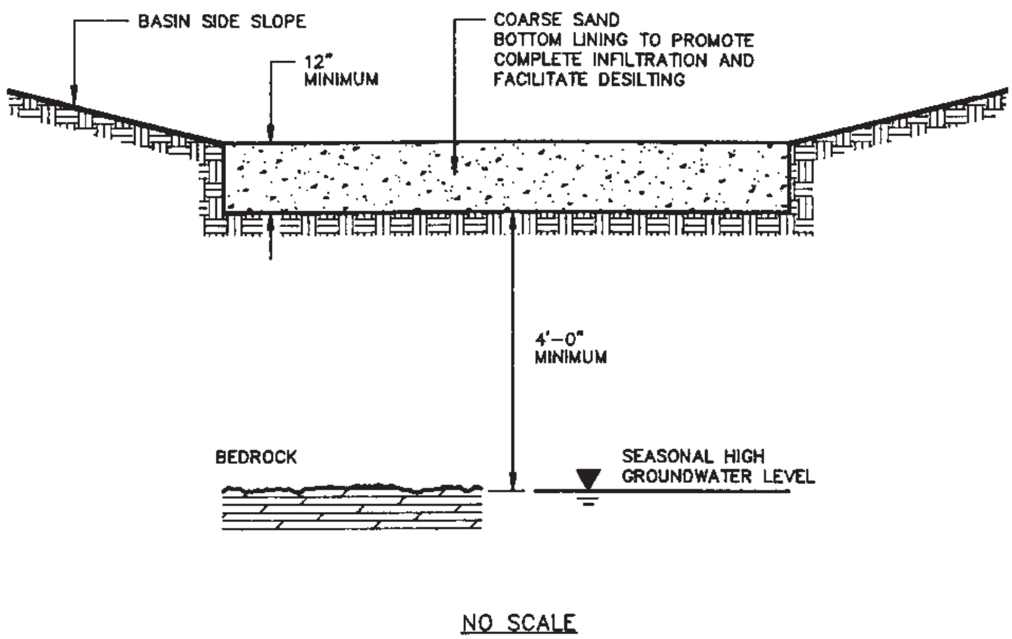
NO SCALE

NOTE: GABION BASKETS ARE RECOMMENDED OVER LOOSE STONE TO PROVIDE SMOOTH TOP SURFACE WHICH WILL FACILITATE MOWING OF BASIN BOTTOM AND TO PREVENT UNAUTHORIZED REMOVAL AND OTHER VANDALISM.

INFILTRATION BASIN UNDERDRAINS TYPICAL DETAILS

FIGURE 3-C

FROM: NJDEP STORMWATER MANAGEMENT FACILITIES MAINTENANCE MANUAL



NONVEGETATED INFILTRATION BASIN BOTTOMS TYPICAL DETAILS

FIGURE 3-D

FROM: NJDEP STORMWATER MANAGEMENT FACILITIES MAINTENANCE MANUAL

Chapter 4
Programmatic and Regulatory Aspects

1. OVERVIEW

There are many important aspects of stormwater management system maintenance. These include planning and design considerations, proper construction, inspection, compliance, and funding. Equally important, though, are institutional or programmatic considerations. The institutional framework must establish a legal basis to assure program maintenance requirements are met. This must include criteria establishing minimum standards for stormwater system inspection and maintenance - requirements that all owners must comply with to ensure the long term performance of their systems.

There are several program components which must operate cooperatively if maintenance efforts are to be effective. Initial requirements must include proper planning and design to assure that the stormwater management system, including each of its components, can be effectively maintained and properly operated. Stormwater program funding, which is beyond the scope of this handbook, is essential to assure proper design review, inspection during construction, and regular inspections of completed facilities. Funding also must be available for development of design, construction, and maintenance guidelines, and to actually perform needed maintenance activities. Educational programs are also important. The importance of proper operation, maintenance, and management of stormwater systems must be understood by designers, developers, contractors, the public, and owners of urban runoff controls. The stormwater program's institutional framework must not only create these important components, but assure that they are fully coordinated.

Constructed wetland serving a residential community showing good site stabilization.

Programmatic aspects of stormwater system operation and maintenance must include recognition of the roles of the various levels of government involved in program implementation (WMI, 1997). It is important that requirements made at the various levels of government (federal, state, regional, local) be complementary and not duplicative or conflicting. ***Stormwater system operation, maintenance, and management must be addressed by the urban runoff control program whenever it requires the use of BMPs. How explicitly or detailed stormwater system maintenance is addressed varies, depending on the degree of regulatory control exerted by each level of program implementation***.

This chapter will provide recommendations on how stormwater programs can assure that BMPs actually are maintained and operated properly. It will review the role of EPA, state government, and local governments in stormwater system operation and maintenance. Examples of successful institutional approaches will be presented as will specific regulatory language on stormwater system operation and maintenance. The final subsection of this chapter contains recommendations relating to public versus private maintenance of completed stormwater management facilities.

The recommendations are based on the most effective approach to ensure the future maintenance of completed stormwater management systems. The recommendations may appear idealistic, but they are based on experiences by several successful state and local urban runoff control programs around the country. They reflect the most optimal approach to stormwater management system operation, maintenance, and management which appears to be available at this time.

1.1. Intended Readers

Intended readers of this Chapter include:

- **Persons involved in developing and implementing stormwater management programs and their associated regulations.**

- **Elected and public officials** who are responsible for developing, promulgating, and/or interpreting stormwater management programs and regulations.

- **Stormwater system designers and builders** who must assure that their systems comply with relevant regulations.

- **Land developers, consultants, and stormwater facility owners** who must receive regulatory approval for their stormwater systems.

2. ROLES OF GOVERNMENT

Experience has shown that successful stormwater management programs are built upon a partnership among the different levels of government involved in program implementation (WMI, 1997). Until recently, stormwater programs were implemented by state and local governments using legal authorities established in state or local laws. However, in 1990, the EPA established federal stormwater permitting requirements under the NPDES program. These federal requirements have stimulated greater awareness of stormwater problems, the need for stormwater treatment, and the implementation of stormwater BMPs.

Whenever BMP implementation is required, stormwater system operation and maintenance requirements must be explicitly stated and enforced. With at least three levels of government often involved in program implementation, it is very important that program requirements be complementary, not conflict, and not create duplication. Stormwater maintenance considerations should be somewhat general at the federal level, with state, regional, or local programs having progressively more detailed program requirements. These requirements must then be implemented by individual property owners or public entities, with some type of compliance mechanism to assure that maintenance is actually performed.

This hierarchical approach begins with general language that requires entities implementing urban runoff control programs to adopt more specific requirements for the long term operation, maintenance, and management of stormwater management facilities. Importantly, this allows the individual jurisdictions to determine, through their existing program framework, how the requirements should be implemented. ***Having minimum standards is important, but the key to successful***

implementation is providing flexibility to attain the standards within the institutional framework of the stormwater program, whether at the state, regional, or local level. Since stormwater systems are an essential part of the local infrastructure, local governments are the most appropriate level of government to assure proper construction, inspection, and maintenance of stormwater management facilities. At times, regional or watershed-based entities may be involved in the day to day implementation of stormwater management programs, including operation and maintenance of stormwater systems. Except for highway departments, state agencies usually will not be directly involved in stormwater system operation, maintenance, and management. Instead, they often will be responsible for establishing performance standards and BMP design criteria, reviewing plans or permitting BMPs, and they will have more of an oversight and technical guidance role. Similarly, except in those few states which are not delegated NPDES stormwater permitting, EPA's role will be to set basic program goals and requirements, and oversee implementation by states.

3. FEDERAL STORMWATER PROGRAMS

Various federal programs (i.e., Sections 319 and 402 of the Federal Clean Water Act, Section 6217 of the CZARA of 1990) may require the implementation of stormwater management programs by states, regional, or local governments, or stormwater BMPs by property owners. Consistent with the hierarchical approach discussed above, these programs have fairly general requirements for stormwater system operation and maintenance. For example, the NPDES stormwater permitting requirements for municipal separate storm sewer systems (MS4s) states "the applicant must include a description of maintenance activities and a maintenance schedule for structural controls to reduce pollution..." Since the implementation of BMPs to treat stormwater is still a new concept, experience has shown that additional guidance on BMP operation and maintenance is needed. ***More specific guidance and program requirements should be adopted by state, regional, or local governments***. For example, the stormwater staff at the Florida Department of Environmental Protection developed a table of recommended BMP inspection frequencies and maintenance activities (Appendix 4-5). EPA Region 4 is including this table in MS4 permits issued to Florida local governments. The table is only guidance and is intended to serve as a starting point for local governments to develop and implement effective BMP inspection and maintenance programs. The recommendations in the table are not enforceable permit conditions, simply guidance. Additional, more detailed BMP inspection, operation, and management language that could be included in state, regional, or local program requirements is discussed in the next section.

4. STATE STORMWATER MANAGEMENT PROGRAMS

This section will discuss institutional aspects of stormwater system maintenance in those states which have aggressively implemented a comprehensive statewide stormwater management program. This is not the rule but the exception. ***Only five states currently have statewide programs which require implementation of stormwater BMPs by new developments***. In those states without a comprehensive program, or where state requirements are permissive, or where state legislation enables but does not require local implementation, many of the requirements for long term performance of stormwater systems will be of interest to or implemented by local governments.

States may have a similar role to EPA in terms of overall program guidance, but they also have a greater capability to establish additional legislative and regulatory requirements for maintaining stormwater systems than are possible at the federal level. In some programs, the state is the permit issuing authority requiring the implementation of stormwater management facilities. In other programs, implementation responsibilities are shared by the state with regional or local governments.

This section will highlight several innovative approaches used around the country which could be adopted as stormwater management program components to significantly improve the long term performance of stormwater management systems. It will also provide recommended language that should be included in state law and in stormwater regulations, whether they are implemented at the state, regional, or local level.

4.1. Program Guidance and Requirements

Several states have implemented stormwater management programs to minimize flooding and the water quality impacts resulting from stormwater discharges associated with new development. ***However, there is general recognition by states that they alone cannot effectively implement stormwater management programs at the state level. Most of these comprehensive statewide programs have, as their foundation, a "watershed management team" approach. Implementation involves a lead state agency along with some combination of regional, local, or watershed-based entities***. Often the lead state agency permits projects undertaken by federal or state government and by the regional or local entities involved in program implementation. Permitting of other projects is done by the regional, local, or watershed-based entity to which the state has delegated program implementation.

In these stormwater management programs, ***the roles of the various implementing entities must be explicitly stated to avoid conflicts and duplication***. Accordingly, states, generally through legislation and regulation, establish the program's minimum goals and performance standards, its administrative procedures, and specify the minimum program components that regional, local, or watershed entities must implement to be delegated the program's administration. The actual structure of the implementing agency program depends on considerations such as the entity's organization, funding mechanism, and the priority of the stormwater program.

States can, and should, be more specific than federal agencies when establishing minimum stormwater management program standards. These standards must be developed with the recognition of impacts that they will have on the resource needs of the regional, local, or watershed agency. If the standards are absolutely necessary (as most are), the state agency must provide assistance - financial, technical, and in securing political acceptance for the program at the local level. Program requirements must be directly related to effectiveness but also be realistic and include some flexibility. Implementing agencies must be allowed to prioritize program components to fit their situation.

The stormwater program's institutional framework, goals, and procedures need to be established legislatively. General program requirements for stormwater system maintenance needs to be included in this legislation. More explicit and detailed requirements should be provided in the program's implementing regulations and guidance materials, such as its BMP manual.

4.2. State Stormwater Legislation

State legislation provides the legal authority for the stormwater program. If program implementation can be delegated to regional or local governments, state law also provides the legal backbone for these programs. In such cases, the law also needs to establish criteria for delegation to assure that the program is implemented consistently statewide.

In general, the state stormwater legislation should be relatively simple without lots of details, especially with respect to the design, construction, and maintenance of stormwater systems. ***More explicit details can be established in the program's implementing regulations***. The maintenance component of state legislation should provide a basic framework to assure that stormwater systems are operated and maintained properly. It must include compliance and enforcement mechanisms and procedures, including penalties. A section of the legislation should allow for regulations, and specify the program areas in which requirements can be set by the rules.

Example legislative language might include:

> The Department (the program's lead agency) shall develop regulations to specifically guide program implementation. The regulations may include, but not be limited to, the following:
>
> 1. Criteria for local program implementation or delegation.
> 2. Types of activities that require an urban runoff control approval.
> 3. Waivers, exemptions, and variances.
> 4. ***Plan approval and inspection fees including construction or maintenance performance bonds.***
> 5. Authority for a local stormwater utility.
> 6. Specific design criteria.
> 7. Permit application and approval process.
> 8. ***Operation permit requirements and time frames.***
> 9. ***Development and implementation of mandated educational programs relating to site inspection of active and completed stormwater management systems.***
> 10. Requirements for any other educational programs.
> 11. ***Inspection requirements, including certification of inspectors.***
> 12. ***Maintenance requirements once construction has been completed.***
> 13. ***Penalty provisions in the event of noncompliance with either design, construction, or operation of stormwater management systems.***

As can be seen from the italicized and bolded text, maintenance aspects of program implementation overlap with many other design and construction requirements.

Incorporating in the law the ability to adopt rules to establish maintenance requirements allows for greater flexibility and for program evolution. It is important to remember that the design, maintenance, and operation of stormwater BMPs is a relatively young field. When changes need to be made to enhance program or BMP effectiveness, it is much easier to amend rules than legislation.

There are a several state laws and regulations which should be reviewed before developing legislative language for a statewide stormwater management program. These include:

1. Delaware:
   - Chapter 40, title 7, Delaware Code, Erosion and Sediment Control and Stormwater Management Act;
   - Sediment and Stormwater Regulations

Contact:
Delaware Department of Natural Resources and Environmental Control
Division of Water Resources
89 Kings Highway
Dover, Delaware 19903

2. Florida:
   - Section 403.0891, Florida Statutes, State, Regional, and Local Stormwater Management Plans and Programs. Also, Section 403.0893 - Stormwater Utilities and Section 403.0896 - Training and assistance for stormwater personnel.
   - Section 62-40.432 (State Water Policy) Stormwater treatment performance standards;
   - Chapters 62-25 (FDEP stormwater regulations) or 40C-42 (SJRWMD rules), Florida Administrative Code.

Contact:
Florida Dept. of Environmental Protection
Nonpoint Source Mgmt. Section (MS3570)
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

3. Maryland
   - Environmental Article, Title 4, Subtitle 1 - Sediment Control and Subtitle 2 - Stormwater Management.
   - Code of Maryland Regulations 26

Contact:
Maryland Department of the Environment
Stormwater Management Program
2500 Broening Highway
Baltimore, Maryland 21224

4. New Jersey
   - N.J.S.A. 40:55D-1, Stormwater Management Act.
   - N.J.A.C. 7:8 Stormwater Management regulations.

Woody vegetation growing on a pond embankment because of a lack of mowing.

Contact:
N. J. Dept. of Environmental Protection
Stormwater Management Program
401 East State Street
Trenton, New Jersey 08625

5. Washington
   - Chapter 90.70 Puget Sound Water Quality Authority
   - Chapter 173-275, Washington Administrative Code (W.A.C.), Stormwater Management in the Puget Sound Watershed.
   - Chapter 400-20, W.A.C. Puget Sound Water Quality Authority.

Contact:
Washington Dept. of Ecology
Stormwater Management Program
P.O. Box 47600
Olympia, Washington 98504-7600

Recognize that the ideal program will contain a mixture of ideas and language from other programs, in addition to original language necessary to address state specific considerations. No program is perfect.

Penalty provisions (Item 13 above) are critical to ensuring the continued operation of stormwater management facilities. A review of 32 stormwater management programs around the country indicates the need for penalty provisions (WMI, 1997). Generally, penalty provisions will not be used very often. Clear statutory authority for them, however, helps to assure maintenance activities are accomplished, especially when needed at sites with reluctant owners.

There is a question of whether penalties should be civil and/or criminal. T***here is a great reluctance to use criminal penalties due to the severity of the impact in the event of a conviction. Consequently, the most commonly used penalty to ensure compliance is a civil action***. This generally results in some form of monetary penalty. Example statutory penalty language might be the following:

> "Any person who violates any rule, regulation, order, or condition imposed on an approved plan or other provision of the Law shall be fined not less than $_____ or more than $_______ for each offense. Each day that the violation continues shall constitute a separate offense."

The dollar amounts of penalties vary widely around the country. Representative levels range from $100 to $5,000.

Existing stormwater programs have found that the most effective compliance tool is a "stop work order". This administrative mechanism is particularly useful during the construction phase of development as it prevents any further work until the site's controls are in compliance with the site plans or permit requirements. Example statutory language follows:

> "The Department shall have the power to issue a cease and desist order to any person violating any provision of this Chapter by ordering such person to stop any site work activity other than those actions necessary to achieve compliance with this law or its implementing regulations."

Another widely used alternative to fines to assure maintenance and management of stormwater systems is authority for the government (state, regional, local) to perform the maintenance and bill the owner. Example statutory language for this concept is:

> "If the owner or responsible maintenance entity fail to maintain the stormwater management system to acceptable standards, the (unit of government) shall issue a written notice specifying actions to be taken in order to bring the system into compliance with its approved design and performance. If these actions are not completed by the time specified in the written notice, the (unit of government) shall perform or contract for this maintenance and bill the owner or maintenance entity for all costs. If the owner of maintenance entity fails to pay the bill within 60 days, a tax lien for the amount of the bill plus ten percent shall be placed upon the property."

It is recommended that the operation and maintenance violations be considered a civil offense, but that a criminal provision also be included for obvious deliberate violations. Penalties are applied most commonly for poor erosion and sediment control at construction sites. They are less commonly imposed for improper construction, maintenance, or operation of permanent stormwater management facilities.

Where there is a significant maintenance requirement that may be controversial, it should be stated in law. The following three examples are provided for consideration by other stormwater management programs.

1. Florida Stormwater Operating Permit

Florida's stormwater program recommends that regional water management districts and local governments issue renewable operating permits for completed stormwater systems. ***These require an annual inspection and certification that the stormwater system is being maintained and is performing as permitted***. This is an excellent approach to ensure that systems are regularly inspected and properly maintained. The approach has general applicability to other stormwater programs and implementation can be tailored to a program's institutional framework.

The legislative framework for Florida's stormwater program includes Section 403.0891, Florida Statutes, which sets forth the stormwater responsibilities of the Department of Environmental Protection, the five regional water management districts, and local governments. The specific criteria and implementation procedures for the Operating Permit System are detailed in stormwater regulations, especially those of regional water management districts or local governments. For example, the City of Tallahassee's Environmental Management Ordinance includes Section 46, entitled Stormwater Management Facility Operating Permit.

One reason this approach has strong merit is because eventual property owners (residential owners especially) are seldom aware of their obligations to maintain stormwater management facilities. ***Requiring owners of stormwater systems to have an Operating Permit helps make system owners aware that they have legal operation and maintenance obligations***. When the responsible legal maintenance entity is a Property Owners Association, the Operating Permit System helps assure that the Association assesses the individual property owners for their portion of the costs incurred when contracting for stormwater system maintenance. The submittal by the responsible maintenance entity of the annual certification and of the information periodically required to renew the Operating Permit also helps to reinforce continued awareness of maintenance obligations.

2. *State of Washington Maintenance Bonds*

Another option to assure maintenance of completed stormwater management facilities, which may require specific legislative authority, is the posting of maintenance bonds. This is required by the State of Washington as part of its Puget Sound program. ***This law requires land developers to obtain a performance bond for stormwater management facility maintenance***. This helps assure that the stormwater management facility is constructed satisfactorily and that there are no outstanding maintenance needs which would create an immediate hardship on the eventual property owners.

The legal foundation for requiring performance bonds is set forth in Washington's Stormwater Management Regulations for New Development which are imposed within the Puget Sound watershed. Section WAC173-275-060(2)(g) states that "Performance bonding or other appropriate financial instruments shall be required for all projects to ensure compliance with these standards". Another section of the regulations requires a maintenance and operation schedule be provided for all proposed stormwater management facilities and BMPs, along with the identification of the party responsible for maintenance and operation.

3. *Delaware'Certified Site InspectorProgram*

Delaware's stormwater program includes a unique approach to site inspection that

Partially clogged outlet at a detention basin due to not inspecting or maintaining the facility.

requires site inspectors to be certified through a formal training program sponsored by the State. Section 4013 of the state's stormwater legislation (Chapter 40, Title 7) requires individual developers to supply their own "certified" inspectors during construction to improve site implementation of temporary erosion and sediment control and permanent stormwater management facilities. The law also authorizes the state stormwater agency to adopt regulations specifying when certified inspectors are required and establishing the training course that they must attend and pass.

Section 12 of Delaware's Sediment and Stormwater Regulations requires a certified inspector on all projects disturbing over 50 acres and also allows the permitting agency to require one on a case by case basis. Certified inspectors are only required during the construction phase of a project. This section of the regulations also set forth the curriculum for the training course and specifies the inspector's responsibilities. The certified inspector documents site conditions, especially of erosion and sediment controls, on a weekly basis and submits site evaluation forms to the contractor, developer, and appropriate permitting agency.

Although established in Delaware for improving construction practices, the concept could be modified to have a certification program for those individuals, both public and private, who are responsible for inspecting permanent stormwater management systems such as would be required by an Operating Permit System. Similar education and certification programs also can be established for individuals who are actually responsible for conducting maintenance activities. Florida's stormwater program is implementing education programs and voluntary certification in both of the above areas.

4.3. Stormwater Regulations

Regulations are an integral component of urban runoff control programs. Their development and implementation are subject to public review and comment, but they are not subject to formal approval by the state legislative body. As such, it is easier to enact and modify technical requirements that are needed for program implementation and evolution. This is very important in the relatively new field of stormwater treatment where technologies and institutional approaches are rapidly changing.

With respect to stormwater facility maintenance, requirements within the regulations will be significantly more detailed than those specified in the stormwater program's enabling legislation. At the local level, regulations usually are adopted as a local ordinance or law. However, they must still include more detailed program requirements such as those to assure long term maintenance and operation of BMPs. ***Adoption as a local law may make it more difficult to amend program requirements, especially technical ones such as BMP design criteria. A better approach may be to include them in a BMP Manual that is adopted in law by reference***.

A very important aspect of state program implementation is the development of design criteria and guidance. These are needed for program implementation and for individual strategies and practices. When state programs require local implementation or allow for delegation to local governments, it is imperative that guidance be provided on how to achieve state program goals and objectives. ***Typically, this detailed guidance is provided in a BMP Design Manual***.

The state program BMP Manual needs to provide detailed design guidance, including specifics on maintenance requirements and responsibilities, for each practice endorsed or required. ***To assure use of, and compliance with, the BMP Manual's requirements, state stormwater regulations (or local regulations, if applicable) should adopt it by reference. The rules also need to include specific statements requiring all stormwater systems to be designed, constructed, maintained and operated in compliance with the BMP Manual's requirements***. Explicit reference to a formally adopted BMP Manual within state (or local) regulations establishes a legal basis for implementation of complex, technical information. It also allows for relatively easy revision of BMP design guidance as more information is gained about the design and performance of BMPs.

Standing water in a dry detention basin caused by a blocked outlet or bottom slopes which are too flat.

Nearly all of the states that have implemented stormwater management programs have developed a BMP Manual to provide the regulated public with explicit guidance. An example of a state required design manual used to implement stormwater programs at the local level is the "Stormwater Management Design Manual for the Puget Sound Basin (The Technical Manual)", developed by the Washington State Department of Ecology. Others are referenced in Chapter 10.

Beside the traditional design considerations typically contained in a BMP Manual, it or the program's regulations also need to include other important needs related to the successful maintenance and operation of stormwater facilities. ***An example is the need to set aside areas where sediments removed from a stormwater management facility can be placed. The single most expensive part of BMP maintenance is transportation of removed sediments to an appropriate disposal area. By setting aside an area on-site for sediment storage, maintenance costs can be significantly reduced thereby increasing the likelihood that the facility will actually be cleaned out when needed***.

A detailed discussion of concerns associated with disposal of sediments removed from stormwater management facilities, along with general recommendations, can be found in Chapter 9. The issue of sediment disposal must be addressed in program implementation, and needs to be considered during the initial review of a proposed development or stormwater management facility. The rule language recommended in Appendix 4.2, establishing the size of a set aside area, is applicable to facilities receiving expected pollutant loadings from residential lands or light commercial uses. Requirements for land uses with higher pollutant loadings would need to be considered individually.

4.4 Example Language That Should Be Contained in State (or Local) Stormwater Management Regulations

Example language which should be considered for inclusion in stormwater regulations is presented in Appendix 4-1. Also included is a brief discussion of key issues, for four major BMP implementation areas, which need to be addressed when developing a stormwater regulation or law. Whether these requirements are established in statewide regulations, or within regional or local government regulations, will depend on the stormwater program's implementation framework.

5. LOCAL STORMWATER MANAGEMENT PROGRAMS

Most local governments have some type of stormwater management program, such as flood protection, and provide stormwater infrastructure. ***In those states without a comprehensive stormwater management program, the local stormwater law or regulations should include all of the recommendations included in the previous section of this chapter***.

Even in those states with statewide stormwater management programs, local governments usually have an important implementation role. Depending on the state program's framework, the local role may include design review and permitting, inspections during or after construction, compliance, maintenance, or master planning. ***Since local governments typically provide infrastructure such as the community's master stormwater system, they have a more vested and direct interest than state or regional agencies in assuring that all of the stormwater systems within the community are being maintained and operating properly***. This is not only to minimize potential flooding but also to limit the local government's liability under Federal or state environmental laws since the master stormwater system almost always discharges ultimately to a water body. Additionally, if the local government has implemented a stormwater utility, especially one with credits for on-site stormwater management, assuring periodic inspections and proper maintenance of privately owned stormwater systems is especially important.

For the above reasons, along with the difficulty that state stormwater agencies have in obtaining sufficient staff to conduct regular inspections of completed stormwater systems, ***it is strongly recommended that local governments implement a Stormwater Operating Permit System***. Possible language for inclusion in a local government stormwater ordinance or regulation is:

Stormwater Operating Permits

1. Subsequent to the final inspection and submittal of the As-built Certification and Record Drawings, no stormwater management systems shall be used until a Stormwater Operating Permit application has been submitted, the required application fee paid, and the application has been approved.

2. All permittees shall operate and maintain the stormwater management system in a manner consistent with the authorized Operating Permit and any other state or local requirements.

3. The following information shall be required in the Operating Permit application:

A. A property parcel map showing the locations and tax parcel numbers of each parcel for which an owner is required to either obtain an operating permit or maintain membership in a Stormwater Facility Property Owners Association.

B. If the permit is to be issued to a Stormwater Management Facility Property Owners Association, a copy of the articles of incorporation and pertinent bylaws must be submitted, along with a list of the names, addresses, and telephone numbers of all Association members and officers.

C. A narrative description of the stormwater management facilities to be maintained and operated.

D. A general location map which indicates the relative location in the watershed , the property tax parcel numbers, and the names and addresses of the current owners of all parcels on which the facilities are located, the limits of the drainage basin contributing to the facilities, and the number of acres contributing runoff to each of the facilities.

E. Information regarding the operating capacities of the facilities, demonstrating that the capacities are not greater than those specified in the applicable permit for the facilities.

F. An operation and maintenance plan, including identification of an individual (including address and telephone number) who shall be designated as the responsible contact individual and who shall be responsible for the day-to-day operation, maintenance, and management of the facility. The plan shall specify operating procedures, possible routine intermittent and annual maintenance, and all other activities required to ensure that the facility performs as designed and permitted. The plan must also include estimates of equipment required, person hours and crew size, schedules, and an estimate of annual costs. Most importantly, the plan must clearly detail how funding and supervision is to be provided.

4. Stormwater operating permits shall expire three years after issuance or renewal. The permittee shall apply for a permit renewal at least three months prior to permit expiration.

5. The stormwater operating permit shall be renewed when each of the following conditions has been met:

A. Inspection by a local government or a state certified inspector that confirms that all components of the facility are in good working order, that the facility is free of debris or excessive sediment deposits and is well stabilized, and that the facility is meeting or exceeding its design performance criteria.

B. If the stormwater operating permit is being renewed by an individual, the applicant must submit updated records providing the names and addresses of current property owners with cross-referencing to the property parcel map filed with the original operating permit application.

C. If the stormwater operating permit is being renewed by a Stormwater Management Facility Property Owners' Association, the applicant shall provide a current list of the names, addresses, and telephone numbers of all Association members and officers, and submit any changes to the Association's bylaws (if any) along with a certification of good standing from the (state agency responsible for corporations).

D. The applicant provides the name, address, and telephone number of the individual responsible for day-to-day operation, maintenance, and management of the facility.

E. The applicant makes any repairs or maintenance activities noted in the inspection report.

6. RECOMMENDATIONS ON PUBLIC VERSUS PRIVATE MAINTENANCE OF COMPLETED STORMWATER MANAGEMENT FACILITIES

Surveys conducted by several stormwater management programs around the country indicate that stormwater systems often are not maintained and operated properly. Maryland's stormwater program has conducted a series of surveys on the maintenance of stormwater practices. The report "Maintenance of Stormwater Management Structures, A Departmental Summary" (Md WRA, 1986) included the following conclusions:

1. Stormwater management facilities in Maryland, especially dry detention facilities, are not particularly well maintained. In fact, a majority of facilities have failed due to lack of routine maintenance.

2. Public facilities are better maintained than private facilities.

3. Commercial/industrial facilities are less likely to be aesthetically unsatisfactory.

4. 45% of commercial/industrial facilities were completely satisfactory, compared to 24% of residential facilities. While there may be several reasons for these results, an important one is that a very clear ownership exists for commercial/industrial facilities. The owner feels more responsibility for the facility and is more likely to maintain it. This is not the case for residential developments, where a Homeowner's Association or the developer is responsible

5. Commercial/industrial facility owners are more concerned about their image, including the appearance of their grounds, than residential facility owners, especially if the residential facility owner is the developer.

The Maryland survey indicates that relying on commercial and industrial property owners to properly maintain their stormwater systems is probably appropriate. They generally either have staff dedicated to maintenance and landscaping activities at their site who can be responsible for stormwater system maintenance, or they contract for such services. However, even these owners need to be periodically checked by public inspectors or through submission of certifications such as required by Operating Permits.

Assuring proper maintenance and operation of residential stormwater systems is much more difficult. Typically, the maintenance of these systems is the responsibility of a Property Owners Association. These entities seldom have the technical expertise to inspect or maintain their stormwater system, and they often lack the commitment to assess their members to raise the funds needed to contract for maintenance. The ***implementation of a Maintenance Agreement or an Operating Permit System can greatly increase compliance by Property Owners Associations. Implementation of education programs, such as Hillsborough County's (FL) "Adopt - a - Pond" program, have also proven successful in getting maintenance done.***

Public ownership and responsibility appear to be the best solution for assuring the long term maintenance and operation of stormwater systems serving residential developments. However, local governments traditionally have been reluctant to accept ownership and responsibility for maintenance of residential systems. Reasons for this include the cost of providing maintenance, potential legal liabilities, and the fact that many stormwater systems are part of a residential development's open space or landscaping areas with associated aesthetic concerns.

Overcoming these obstacles requires sound program administrative requirements for operation and maintenance and, most importantly, an adequate program funding mechanism, such as a stormwater utility. Additionally, ***some local governments have required Maintenance Agreements between the residential development and the local government. A key aspect of these Agreements is the clear delineation of responsibilities. The local government accepts responsibility for inspecting and maintaining the stormwater system's structural components, including the periodic removal of debris and accumulated sediments. However, aesthetic maintenance and pollution prevention still rests with the Property Owners Association***.

7. EXAMPLES OF MAINTENANCE AGREEMENTS

There are several Maintenance Agreements which can be used as examples for other jurisdictions initiating stormwater management programs. ***Three examples of Maintenance Agreements worthy of consideration because of their unique features are presented in Appendices 4-2, 4-3 and 4-4***.

The first two examples are from the City of Olympia, Washington. ***"Residential Agreement to Maintain Stormwater Management Facilities and to Implement a Pollution Prevention Plan" is the first example (Appendix 4-2)***. This agreement is of interest for the following reasons:

1. Maintenance responsibility for sediment removal, managing vegetation in wet ponds, resetting orifice sizes and elevations on residential properties rests with the City.
2. The City clearly defines maintenance responsibilities of the residential property owners.
3. A pollution prevention plan that includes source control of pollutants is formally included in the maintenance agreement.
4. Authority for the City to be reimbursed for maintenance activities undertaken by the City that are the responsibility of the Homeowners Association but are not performed.
5. Requires the submission to the City of an annual report by the Homeowners Association. This helps the Association's members understand and demonstrate their commitment to undertake maintenance obligations.
6. The City obligates itself to an annual inspection of all stormwater facilities.

The second Maintenance Agreement example from the City of Olympia, Washington program is a "Commercial, Industrial Agreement to Maintain Urban Stormwater Management Facilities and to Implement a Pollution Prevention Plan" (Appendix 4-3). This Agreement is more typical and has more universal applicability in other jurisdictions. Maintenance responsibility clearly rests with the property owner, with technical assistance provided by the City. This Agreement contains the following provisions:

1. A pollution prevention plan, including source control of pollutants, is formally included in the maintenance agreement.
2. Authority for the City to be reimbursed for maintenance activities undertaken by the City that are the responsibility

of the property owner but are not performed.

3. Requires submission to the City of an annual report by the property owner again helping the owner demonstrate an awareness and commitment to complete maintenance obligations.

4. The City obligates itself to an annual inspection of all stormwater management facilities.

5. The City has implemented a stormwater utility. One enforcement mechanism in this Agreement allows the City to revoke stormwater utility rate credits for stormwater treatment if required maintenance is not performed.

The third example Maintenance Agreement is entitled "Standard Maintenance and Monitoring Agreement for the City of Alexandria, Virginia" (Appendix 4-4). This Agreement is especially interesting because of a component dealing with "unconventional" stormwater management facilities. The City stresses new technologies for stormwater management in "ultra urban" areas. This agreement obligates the landowner to contribute the entire cost of a water quality monitoring program to assess the performance of the unconventional stormwater management practice before release of the Final Site Plan. This requirement helps the evolution of stormwater management facilities in situations where innovative practices are necessary due to site constraints. The Agreement contains the following provisions:

1. Grants permission to the City to enter the property for inspection purposes.

2. Allows the City to do needed maintenance and assess the landowner for the maintenance costs.

3. Allows the City to assess a monitoring fee for evaluating the performance of innovative stormwater management facilities.

Good access and legal authority help assure that needed maintenance gets performed.

APPENDIX 4-1

Example Language
That Should Be Contained
in State, Regional, or Local
Stormwater Management Regulations

This appendix contains a discussion of essential concepts needed in stormwater regulations to effectively assure the proper design, construction, inspection, and operation and maintenance of stormwater management systems.

Several of the recommended sections might be more appropriately included in a BMP Manual if the program has one. In this case, the regulations need to adopt the Manual by reference and require compliance with the Manual's criteria. These sections are designated by (BMP Manual) at the end of the recommendation.

The recommendations are divided into four major issue areas:

- Design and review requirements
- Construction requirements
- Legal operation and maintenance requirements
- Maintenance inspection requirements

A. Design and Review Requirements for Stormwater Facilities and Plans

Design review requirements need to be considered from several different perspectives:

- Proper design and construction of the stormwater management system to ensure proper performance. Unfortunately, experience has shown that systems often are inappropriately designed for site conditions or are not constructed properly;

- Inclusion of long term maintenance and operation considerations in the design of the stormwater system. This helps assure that maintenance can be done relatively easily. This helps assure that systems will perform for a maximum time frame given their expected design flows and pollutant loadings; and

- Institutional issues such as warranty requirements or review and approval of the legal operation and maintenance entity along with its accompanying legal documents. This provides the legal framework for subsequent inspection and maintenance by a specific entity, either public or private.

Recommended language includes:

1. Stormwater system design will include careful consideration of maintenance as an essential design element. All stormwater management systems and plans shall be designed in accordance with the __________ BMP Design Manual dated ______,with approved supplements.

2. The applicant shall provide a legally dedicated easement with an access road to retention, detention, and filtration facilities from a public right of way. The access road shall be a minimum of 15 feet wide and suitable to allow heavy maintenance vehicles access to all points needed to maintain the facility.

3. Stormwater management facilities serving residential developments and the access roads serving these facilities shall be placed in separate tracts, owned in common by the property owners served by the facility or by the development's Property Owners Association.

4. Projects reviewed and approved for sediment control and permanent stormwater management shall have a certified site inspector (may want to limit type of activity, e.g., projects over 5 acres, etc.). The certified site inspector shall be responsible for the following items:

   A. Inspection of active construction sites on at least a weekly basis.
   B. Submitting a completed inspection form which documents site conditions to the contractor, developer, and permitting agency within five calendar days.

5. It shall be the responsibility of the permittee to maintain all erosion and sediment control and permanent stormwater management facilities in good operating condition during the lifetime of the permit. The permittee shall clean and repair or replace all erosion control practices as often as necessary to maintain their effectiveness and level of performance, or as directed by a certified inspector or by the permit authority. In addition, the permittee shall be responsible for assuring that any practices damaged during floods, storms, or other adverse weather conditions are returned to normal operating conditions within a defined time frame as determined by the certified inspector or permitting agency.

6. Land area adjacent to the stormwater management facility must be set aside for disposal of sediments removed from the facility when maintenance is performed. The land set aside for facility maintenance shall be sized as follows: (only suggested sizing)

A. The set aside area shall accommodate at least 2% of the stormwater management facility volume to the elevation of the 2 year storm storage volume elevation,
B. The maximum depth of the set aside volume shall be one foot,
C. The slope of the set aside area shall not exceed 5%, and
D. The area and slope of the set aside area may be modified if an alternative area or method of disposal is approved by the appropriate plan approval agency. (BMP Manual)

7. A clear statement of defined maintenance responsibility, an operation and maintenance schedule, and the specific parties responsible for maintenance shall be established during the plan review and approval process.

8. Prior to the issuance of any building or grading permit for which stormwater management is required, the responsible plan approval agency shall require the applicant or

owner to execute an inspection and maintenance agreement binding on all subsequent owners of land served by the private stormwater management facility. Such agreement shall provide for access to the facility at reasonable times for regular inspection by an inspection agency.

B. Construction Requirements for Stormwater Management Systems

Construction activities can have a significant negative impact on the short or long term performance of stormwater management facilities. ***Improper control of pollutants, especially sediments, during site construction, or improper construction of the stormwater management facility itself, can significantly reduce the expected performance and lifespan of the facility. Criteria and recommendations to address both of these situations are needed to ensure long term performance***.

1. *Protection of Permanent Stormwater Management Facilities From Premature Failure Caused By Pollutant Entry During Site Construction.*

To a large extent, the treatment performance of stormwater management facilities depends on the available storage volume. In addition, several treatment practices rely upon the permeability of surrounding soils or filter media. Consequently, excess sedimentation can significantly reduce treatment performance or prevent proper functioning of the facility.

The practical aspects of site control during construction are discussed in Chapter 6. However, ensuring effective site control during construction and protecting stormwater management facilities from entry of construction site pollutants, especially sediments, also requires a strong legal foundation. Typically, the program's regulations adopt by reference its BMP Manual, and requires all plans and stormwater systems to be designed, constructed, operated, and maintained in accordance with the Manual's requirements. The program's BMP Manual needs to include specific recommendations for each of the different practices, along with general statements meant to cover all stormwater management facilities.

The following recommendations are directed towards structural stormwater management practices. However, it is extremely important to implement nonstructural, pollution prevention practices on all projects with structural stormwater management practices. These nonstructural controls serve as an overlay applicable to all types of structural stormwater management practices.

Recommended language includes:

Stormwater Detention Practices

Detention practices are often used for sediment trapping during construction. When the approved erosion and sediment control plan uses a permanent detention facility for sediment control, the following requirements should be included in the stormwater regulations or in the BMP Design Manual:

1. The detention facility shall be installed in compliance with all approved design requirements and specifications. Special attention shall be paid to installation of the principal spillway cradle, anti-seep mechanisms (whether collars or diaphragm), core trench, compaction, and emergency spillway.

2. The principal outlet structure shall have a temporary structure attached to it which provides effective filtering of sediments prior to the release of runoff from the site. This temporary structure can either be a riser attachment surrounded by filter fabric and stone, or a horizontal pipe at the foot of the riser assembly which extends horizontally on the detention facility bottom and is covered by filter fabric and stone. Other filtering variations should be considered depending on their use, performance, and experience within the stormwater program. (BMP Manual)

3. Sediment cleanout must be accomplished before the detention facility storage to the crest of the principal spillway is reduced by 25% (may be more stringent depending on the specific jurisdiction). (BMP Manual)

4. Removal of the temporary sediment control modifications to the outlet structure shall be done only after the site has been vegetatively stabilized in accordance with the approved erosion and sediment control plan and the detention system's design bottom elevations have been met. (BMP Manual)
5. Wetland plantings, where required, shall not be performed until final site stabilization has been accomplished. (BMP Manual)

Infiltration Practices

Infiltration facilities are extremely sensitive to clogging by construction generated sediments. Therefore, stringent requirements are needed during construction to assure their long term performance once construction activities are completed. ***The following recommendations may be controversial. They need to be discussed thoroughly by the implementing agency and with the regulated community to recognize difficulties in implementation and gain support for their inclusion in the program***.

1. Infiltration facilities should not be constructed or operated prior to overall site stabilization. (BMP Manual)

2. Infiltration facilities, other than dry wells and porous pavement, shall be off-line and have pretreatment practices to reduce sediment loadings into the facility. Pretreatment can be provided by sediment sumps, biofiltration, extended detention ponding, or other means approved by the permitting agency. (BMP Manual)

3. Infiltration basin facilities shall not be used as sediment basins during construction. Sediment basins shall be constructed upstream of the infiltration basin and construction runoff shall bypass the infiltration basin until site stabilization has been completed. (BMP Manual)

4. To prevent soil compaction, areas to be used for infiltration facilities will be clearly marked and construction equipment prevented from entering them. (BMP Manual)

Filtration Practices

Treatment in filtration practices is accomplished by passing runoff through a filter media. They often are used as a component of construction site sediment control. However, filters used for stormwater treatment need to have certain requirements placed upon them to better assure long term performance:

1. If used to filter sediments during construction, the filter media shall be completely replaced once the site is fully stabilized and before the filter is placed into operation for stormwater treatment. (BMP Manual)

2. If not used during construction for filtering sediments, runoff shall be diverted around the filter and filter media shall not be placed in the facility until the contributing drainage area has been stabilized. (BMP Manual)

3. Underdrain or outlet structures shall be protected from excess sediment entry. (BMP Manual)

Biofiltration Practices

Biofiltration practices rely on vegetative filtering of stormwater runoff and, in many cases, infiltration. Their effective performance depends on their length, slope, soils, vegetative stand, and flow velocity. As such, activities which may adversely impact on any of the treatment mechanisms should be addressed during construction.


Barrel/riser assembly installed upside down demonstrating a lack of understanding by the contractor and lack of inspection oversight

1. If the biofiltration practice will rely upon infiltration, then all recommendations for infiltration facilities need to be followed for biofiltration practices. (BMP Manual)

2. The facility shall be protected from excess sedimentation which could retard or smother vegetation, or impair percolation. (BMP Manual)

3. Biofiltration facilities can be used as a component of an erosion and sediment control plan, but primarily as a secondary sediment trapping facility. Examples include treatment of stormwater flows after discharge from a sediment trap, or sheet flow from a

residential site into a biofiltration facility which, during the erosion and sediment control phase, has stone check dams to reduce flow velocities. Before being placed into service for stormwater management, biofiltration facilities will be cleared of all accumulated sediments, excavated to the design depth, and vegetatively stabilized. (BMP Manual)

4. Once the biofiltration practice has been shaped to final contours, it shall be sodded or erosion control matting or other practices shall be used to protect the soil and grades until vegetation has become established to minimum density requirements. (BMP Manual)

2. Ensuring Proper Construction of the Stormwater Management Facility

To help assure that stormwater systems are constructed properly, three essential institutional components need to be included in the stormwater program: financial assurances, periodic inspections and as-built certifications. Recommended rule language includes:

Financial assurances

1. Prior to the issuance of any building or grading permit for which stormwater management facilities are required, the plan approval agency shall require the applicant or owner to submit a financial guarantee to ensure the initial function of the completed stormwater management facility. That guarantee shall be either a surety or cash bond, or irrevocable letter of credit. The amount of the guarantee shall be established by the plan approval agency but shall not be less than 50% (actual percentage can be determined by individual state program) of the estimated construction cost of the stormwater management system.

Periodic inspections

The inspection entity, whether a public agency, state certified inspector, or site engineer, must have a visible presence during construction of stormwater management facilities. ***Inspections need to be made at specified stages of construction rather than at an assigned time frequency***. Construction phasing may mean that a stormwater management facility may not be actively under construction for extensive time periods. Therefore, communication between contractor, consultant, and the inspection entity is critical. The following steps should be taken to assure inspections are conducted at the appropriate stages of construction:

1. The land developer shall notify the inspection entity before initiation of construction, at the construction stages specified below, and upon project completion, when a final inspection will be conducted to ensure compliance with the approved plan.

2. The land developer or contractor shall request an inspection at least 24 hours ahead of time. Inspectors will be required to approve work as it is completed at the critical

stages of construction specified below for the different types of stormwater management facilities.

3. The approved stormwater management system plans shall be on the project site at all times during construction.

4. Site personnel shall be notified of any site inspection and receive a written report of site conditions. The report shall specify any corrections that are necessary to bring the site and the stormwater management facility into compliance with approved plans.

5. All stormwater detention systems shall be inspected at the following stages of construction:

   A. Upon completion of excavation to sub-foundation and, where required, installation of structural supports or reinforcement for structures, including, but not limited to:
   (1) Core trenches for structural embankments,
   (2) Inlet-outlet structures and anti-seep structures, watertight connectors on pipes, and
   (3) Trenches for enclosed storm drain facilities.
   B. During placement of structural fill, concrete, and installation of piping and catch basins;
   C. During backfill of foundations and trenches;
   D. During embankment construction; and
   E. Upon completion of final grading and establishment of permanent vegetation.

6. Infiltration facilities shall be inspected at the following times:

   A. When the area to be used for the infiltration facility has been staked out prior to its construction;
   B. During excavation to ensure minimal compaction and verify soil conditions;
   C. Upon completion of excavation and, if appropriate, before filling of the facility with stone or other fill material; and
   D. Upon completion of facility construction, including complete establishment of vegetation, if appropriate.

7. Filtration facilities shall be inspected at the following times:

   A. Upon completion of excavation;
   B. Upon completion of structural components, such as reinforcing bars, but prior to any concrete pouring;
   C. For prefabricated units, during joining of prefabricated sections to ensure good sealing between sections;
   D. After the facility has been filled with water to determine whether there is any leakage: and
   E. For sand filters which are part of a detention system, inspections shall occur as specified for detention facilities and before and after placement of underdrain pipes, geotextile fabrics, and filter media.

As-built Certifications and Record Drawings

1. Completed construction of the stormwater management system shall be documented on an As-built Certification and Record Drawing, prepared and sealed by a construction professional. Normally, this is the registered professional engineer who has supervised the construction of the stormwater system. These documents certify that construction of the stormwater management system was done according to the approved plan. Any variation from the approved plan must be noted.

2. Prior to requesting a final inspection, the permittee shall have a registered professional engineer, or other qualified design professional (depending upon state or local requirements), inspect the stormwater management system, submit a complete set of drawings, and certify on the plans that:

   A. The stormwater management facilities were constructed in compliance with the approved plans. The Record Drawings will show all pertinent constructed dimensions, elevations, shapes, and materials;
   B. All variations in construction from the approved design plan shall be identified, including omissions to and additions from the approved plan;
   C. If there are modifications from the approved plan, what changes or improvements are required to bring the project into compliance with the approved plan; and
   D. Any changes which might conflict with local, state, or federal regulations.

C. Legal Operation and Maintenance Requirements for Stormwater Systems

A very important element which must be considered during the design phase is determining how to assure proper operation and maintenance of the stormwater system, both for the short and long term. ***For the short term, it is recommended that there be a warranty period during which the original developer of the site is responsible for all maintenance and operation. However, for the long term, a permanent operation and maintenance entity must be identified which has appropriate legal authority to own, operate, maintain the stormwater system, and raise funds to complete maintenance when needed***.

When there is one property owner, the maintenance responsibility is clearly defined. ***However, a major concern arises when the owner or permittee involved in development and implementation of site controls eventually sells all or part of the property***. The new owners often will not be aware of permit requirements and will find that they have a permanent stormwater management facility on their property that they must inspect and maintain. This problem is especially compounded at residential developments, where there will be many different property owners. ***Typically, a property owners association will be responsible for stormwater system operation and maintenance. Experience in urban runoff control programs around the country shows that, even with the best intentions, maintenance of stormwater management facilities by these associations generally is not accomplished*** (WMI, 1997).

Example wording for both situations follows :

General Assurances

1. The owner or permittee shall assure that the stormwater management system is at all times properly operated, maintained, and managed in accordance with the requirements of the permit and the approved stormwater pollution prevention plan.

2. Stormwater management facilities shall be maintained so that their performance is not diminished or impaired. Failure to maintain stormwater facilities shall be considered a permit violation and subject the responsible maintenance entity to any and all penalties established by law or these regulations.

3. Stormwater management systems shall not be modified without specific approval of the permitting agency unless such modifications are part of an approved maintenance schedule.

4. Stormwater management facilities shall be located on commonly owned property and not located on one individual's property unless that individual accepts full maintenance responsibility for the facility. There shall be dedicated easements for access to all components of the stormwater management system.

5. The owners, with a record interest in any non-public stormwater management facility, commercial, industrial, and other private practice, shall sign and record a covenant which runs with the land and binds the property on which the private stormwater management facility is located to maintain the facility.

6. An operation and maintenance plan and schedule shall be provided to the owner or the legal operation and maintenance entity.

7. The appropriate public inspection agency shall have authority to inspect private stormwater management facilities at any time to ensure compliance with maintenance schedules and requirements, and that the facilities are operating as designed and constructed.

Warranty Period

1. The permittee shall be responsible for all maintenance and proper operation of stormwater facilities for a period of two years after completion of the overall project. The permittee shall satisfactorily maintain the facility and repair any failure within this two year period. Additionally, the permittee shall post and maintain a maintenance bond or other security acceptable to the permitting agency during this two year initial maintenance period. The purpose of the maintenance bond is to cover the cost of design defects or failures in workmanship of the facilities. The amount of the maintenance bond shall be ten percent of the construction cost of the stormwater management facilities.

2. The permittee shall be responsible for proper operation and maintenance of the stormwater system. If the permittee is going to sell or otherwise divest its interest in the permitted development or property, then a legal operation and maintenance entity, as specified below, shall be accept responsibility for the operation and maintenance of the stormwater system.

3. The permittee shall give the responsible maintenance entity copies of possible maintenance inspection forms and other appropriate documentation to educate them about their legal responsibilities of owning a stormwater management system.

4. The permittee shall provide a copy of an "as-built" plan of the stormwater management system to the responsible maintenance entity.

Legal Operation and Maintenance Entity

1. The following entities are acceptable for meeting the requirements necessary to ensure that the stormwater management system will be operated and maintained in compliance with the requirements of these regulations:

   A. Local governmental units including counties or municipalities, or special taxing districts.
   B. State or federal agencies; or
   C. Duly constituted stormwater, water, communications, sewer, electrical, or other public utilities.

2. The property owner or developer is normally not acceptable as a responsible entity when the property is intended to be subdivided. The property owner or developer shall be acceptable in any of the fol lowing circumstances:

   A. Written proof is furnished either by letter or resolution, that a governmental entity or such other acceptable entity as set forth in 1 above will accept the operation and maintenance of the stormwater management system at a specified time in the future;
   B. Proof of bonding or assurance of a similar nature is furnished in an amount sufficient to cover the cost of the operation and maintenance of the stormwater management system;
   C. The property is wholly owned by the permittee and ownership is intended to be retained. This would apply to a farm, corporate office, or single industrial facility, for example; or
   D. The ownership of the property is retained by the permittee and is either leased or rented to third parties such as in shopping centers or mobile home parks.

3. Profit or nonprofit corporations including homeowners associations, property owners associations, condominium owners associations or master associations shall be acceptable only under certain conditions that ensure the corporation has the financial, legal and administrative capability to provide for the long term operation and maintenance of the stormwater management system.

4. Entity requirements.

   A. If a multimember association such as a homeowner, property owner, condominium or master association is proposed, the owner or developer must submit Articles of Incorporation for the association, and Declaration of Covenants and Restrictions, or such other organizational and operational documents which affirmatively assign authority and responsibility for the operation or maintenance of the stormwater management system.
   B. The association shall have sufficient powers reflected in its organizational or operational documents to:
   1. Operate and maintain the stormwater management system as permitted or exempted by the approval authority;
   2. Establish rules and regulations;
   3. Assess members a fee for the cost system operation and maintenance and enforce collection of such assessments;
   4. Contract for services to provide for operation and maintenance;
   5. Exist in perpetuity. The Articles of Incorporation must provide that if the association is dissolved, the stormwater management system shall be transferred to and maintained by an entity acceptable to the approval authority. Transfer of maintenance responsibility shall be effectuated prior to dissolution of the association;
   6. Enforce the restrictions relating to the operation and maintenance of the stormwater management system;
   7. Provide that the portions of the Declarations which relate to the operation and maintenance may be enforced by the approval authority in a proceeding at law or in equity; and
   8. Require that amendments to the documents which alter the stormwater management system beyond maintaining it's original condition must receive approval agency approval before taking effect.

5. Phased Projects

   A. If an operation and maintenance entity is proposed for a project which will be constructed in phases, and subsequent phases will use the same stormwater management system as the initial phase or phases, the entity shall have the ability to accept responsibility for the operation and maintenance of stormwater management systems for future phases of the project.
   B. If the development scheme contemplates independent operation and maintenance entities for different phases, and the stormwater system is integrated throughout the project, the entities either separately or collectively shall have the authority and responsibility to operate and maintain the stormwater system for the entire project. That authority shall include cross easements for stormwater management and the ability to enter and maintain the various facilities, should any sub-entity fail to maintain a portion of the stormwater management system within the project.

In the event the legal operation and maintenance entity fails to maintain the stormwater management system in good working condition, the permitting authority or local jurisdiction must have the legal authority to enter the property, maintain the stormwater management system, assess the property owners, and be able to place a lien on the property if the owners do not pay the assessment. This may be necessary for safety reasons or it may be the only way to ensure that the facility is maintained as constructed. There are several examples of legal maintenance agreements provided at the end of this Chapter which offer wording regarding this legal authority.

D. Maintenance Inspection Requirements for Stormwater Management Systems

To assure that the legal operation and maintenance entity is performing all required maintenance activities, periodic inspections and certifications are needed. ***Whether these inspections are done by a public agency, such as the permitting authority, by a state certified inspector, or by a registered professional engineer, will depend upon the stormwater program's institutional framework and staff resources. Unfortunately, due to a lack of adequate funding, most public agencies will never have enough inspectors to regularly inspect completed stormwater management systems***. To address this problem, Florida's program is implementing a certified inspector program and recommending that local governments implement renewable Operating Permits for stormwater systems.

A question that often arises is how frequently should stormwater management systems be inspected to assure proper performance. Often this is site-specific, depending on many factors such as the types of BMPs used, the pollutant loadings, the facility's size, the contributing drainage area, and whether it is on-line or off-line. For example, while wet detention systems may only need annual inspections, BMPs such as oil/grit separators or sand filters may need monthly inspections. ***Chapter 6 provides recommendations on how often different types of BMPs need inspecting. Additionally, Appendix 4-1 includes a table prepared by the Florida Department of Environmental Protection that is included in NPDES municipal stormwater permits.***

Recommended rule inspection language follows:

General Inspection Requirements

1. The permittee or responsible maintenance entity shall conduct regular inspections of all components of the stormwater management. The person conducting the inspection shall complete and retain a stormwater management facility inspection form after each inspection.

2. At least once each year, the permittee or responsible maintenance entity shall arrange for an inspection of their stormwater management system by either a public agency inspector or a private inspector.

3. Inspection reports (detailed in **Chapter 7**) shall be maintained by the responsible inspection agency. The inspection reports shall include the following items:

   A. Date of inspection
   B. Name of the inspector

C. The condition of:
   (1) vegetation,
   (2) fences,
   (3) spillways,
   (4) embankments,
   (5) reservoir area,
   (6) outlet channels,
   (7) underground drainage,
   (8) Filter media,
   (9) sediment load, or
   (10) other items

D. If maintenance activities are needed, the recommendations for maintenance and an expected time for completion of the needed maintenance activities will be noted on the form.

4. The permitting (or inspection) agency shall implement procedures to ensure that deficiencies indicated by inspections are rectified in a timely manner. These shall include:

   A. Notification of the responsible maintenance entity of deficiencies and needed maintenance activities, including a time frame for repairs;
   B. After the maintenance activities have been completed, the inspector will be notified so that the facilities can be reinspected. The inspector will complete a new inspection form, noting whether all recommended maintenance activities have been completed and if any other actions are needed to assure proper operation of the facility.
   C. Effective enforcement procedures or procedures to refer projects to the appropriate legal entity if repairs are not undertaken or are not done properly.

5. Copies of all stormwater management facility "As-Built" Plans shall be provided to the appropriate maintenance inspection agency and to the legal maintenance entity responsible for performing maintenance.

6. All public agency or private inspectors of permanent stormwater management facilities shall attend and pass a Departmental course on stormwater system maintenance. In addition, individuals responsible for maintenance of completed stormwater management facilities shall also be required to attend this stormwater management maintenance course. The course shall include discussion of at least the following topics:

   A. Context of the course.
   B. Aspects of law and regulation.
   C. Soils information including texture, limitations, erodibility, and classification.
   D. Stormwater management facilities and the importance of their proper function and performance.
   E. Inspection and problem documentation.
   F. Proper approach to actual maintenance including erosion and sediment control during maintenance.
   G. Disposal of materials removed from the practice.
   H. Submission of an activity completion form.

Public Agency Inspections

1. The responsible public inspection agency shall conduct inspections of all stormwater management systems at least once per year. More frequent inspections will be conducted after an unusually high runoff event or for stormwater systems with a higher potential to fail such as filters or oil and grit separators.

Private Inspections

1. If there is no responsible public inspection agency, the legal maintenance entity shall provide for period inspections of their stormwater management system by either a registered professional engineer or a state certified inspector.

2. Inspections shall be conducted at least once per year, with more frequent inspections after an unusually high rainfall or for stormwater systems such as filters or oil and grit separators.

3. The inspector shall provide the legal maintenance entity with a copy of all inspection reports and send one to the permitting or responsible inspection agency.

4. The legal maintenance entity shall complete all maintenance activities and repairs recommended in the inspector's report within the time frame specified and request the inspector to reinspect the stormwater system following completion of all maintenance activities.

APPENDIX 4-2

Residential Agreement to Maintain Stormwater Management Facilities and to Implement a Pollution Prevention Plan

Olympia, Washington

Drainage Design and Erosion Control Manual for Olympia, Washington

Residential Agreement to Maintain
Stormwater Management Facilities and to Implement
a Pollution Prevention Plan

The upkeep and maintenance of stormwater management facilities and the implementation of pollution prevention best management practices is essential to the protection of aquatic resources. All property owners are expected to conduct business in a manner that promotes resource protection. This Agreement contains specific provisions with respect to maintenance of stormwater management facilities and use of pollution prevention practices.

LEGAL DESCRIPTION

Whereas, the ____________ have constructed improvements, including but not limited to buildings, pavement, and stormwater management facilities on the property described above. In order to further the goals of the Jurisdiction to ensure the protection and enhancement of aquatic resources, the Jurisdiction and the ______________ hereby enter into this Agreement. The responsibilities of each party to this Agreement are identified below.

________________________ SHALL

1. Implement the stormwater management facility maintenance program included herein as Attachment "A". (maintenance checklist similar to that developed in Chapter 7)

2. Implement the pollution prevention plan included herein as Attachment "B". (homeowner responsibilities such as disposal of household wastes, lawn care, etc.)

3. Maintain a record (in the form of a log book) of steps taken to implement the programs referenced in (1) and (2) above. The log book shall be available for inspection by appointment at _____________________________. The log book shall catalog any action taken, who took the action, when it was taken, how it was done, and any problems encountered or follow-on actions recommended. Maintenance items ("problems") listed in Attachment "A" shall be inspected as specified in the attached instructions or more often if necessary. The ___________ are encouraged to photocopy the individual checklists in Attachment "A" and use them to complete its inspections. These completed checklists would then, in combination, comprise the logbook.

4. Submit an annual report to the Jurisdiction regarding implementation of the programs referenced in (1) and (2) above. The report must be submitted on or before ______, 199_ and each calendar year and shall contain, at a minimum, the following items:

   A. Name, address, and telephone number of the businesses, the persons, or firms responsible for plan implementation, and the persons completing the report.
   B. Time period covered by the report.
   C. A chronological summary of activities conducted to implement the programs referenced in (1) and (2) above. A photocopy of the applicable sections of the logbook,

with any additional explanations needed, shall normally suffice. For any activities conducted by paid parties, include a copy of the invoice for services.

D. An outline of planned activities for the next year.

THE JURISDICTION SHALL:

1. Execute the following periodic major maintenance on the subdivision's stormwater management facilities: sediment removal from facilities, managing vegetation in wet ponds, resetting orifice sizes and elevations, and adding baffles.

2. Maintain all stormwater management facility elements in the public rights-of-way, such as catch basins, oil-water separators, and pipes.

3. Provide technical assistance to the ________________ in support of its operation and maintenance activities conducted pursuant to its maintenance and source control programs. Said assistance shall be provided upon request and as Jurisdictions time and resources permit.

4. Review the annual report and conduct a minimum of one (1) site visit per year to discuss performance and problems with the ______________.

5. Review the agreement with the ________________ and modify it as necessary at least once every three (3) years.

REMEDIES

1. If the Jurisdiction determines that maintenance or repair work is required to be done to the stormwater management facilities located in the subdivision, the Jurisdiction shall give the _____________ notice of the specific maintenance and/or repair required. The Jurisdiction shall set a reasonable time in which such work is to be completed by the persons who were given notice. If the above required maintenance and/or repair is not completed within the time set by the Jurisdiction, written notice will be sent to the ______________ stating the Jurisdiction's intention to perform such maintenance and bill the ______________ for all incurred expenses.

2. If, at any time, the Jurisdiction determines that the existing facility creates any imminent threat to public health or welfare, the Jurisdiction may take immediate measures to remedy said threat. No notice to the persons listed in Remedies (1), above, shall be required under such circumstances. All other _______________ responsibilities shall remain in effect.

3. The _________________ grant unrestricted authority to the Jurisdiction for access to any and all stormwater management facilities for the purpose of performing maintenance or repair as may become necessary under Remedies (1) and/or (2).

4. The __________________ shall assume responsibility for the cost of maintenance and repairs to the stormwater management facilities, except for those maintenance actions

explicitly assumed by the Jurisdiction in the preceding section. Such responsibility shall include reimbursement to the Jurisdiction within 90 days of the receipt of the invoice for any such work performed. Overdue payments will require payment of interest at the current legal rate for liquidated judgements. If legal action ensues, any costs or fees incurred by the Jurisdiction will be borne by the parties responsible for said reimbursements.

This Agreement is intended to protect the value and desirability of the real property described above and to benefit all the citizens of the Jurisdiction. It shall run with the land and be binding on all parties having or acquiring any right, title, or interest, or any part thereof, of real property in the subdivision. They shall inure to the benefit of each present or future successor in interest of said property or any part thereof or interest therein, and to the benefit of all citizens of the Jurisdiction.

Agreed to and signed by:

____

Owner Date

STATE OF WASHINGTON, COUNTY OF THURSTON

On this day and year, the above personally appeared before me and provided photo identification, and who executed the foregoing instrument and acknowledge that they signed the same as their free and voluntary act and deed for the uses and purposes therein mentioned.

Given under my hand and official seal this _____ day of _____________, 199__

Notary Public in and for the State of
Washington, residing in _________________
My commission expires _________________

Dated in Olympia, Washington, this _______ day of _____________, 199__

STATE OF WASHINGTON, COUNTY OF THURSTON

On this day and year, personally appearing before me,_______________________ and _______________________ , who executed the foregoing instrument and acknowledge the said instrument to be the free and voluntary act and deed of said Municipal Corporation for the uses and purposes therein mentioned and on oath states he is authorized to execute said instrument.

Given under my hand and official seal this _____ day of _____________, 199__

Notary Public in and for the State of
Washington, residing in _________________
My commission expires _________________

Dated in Olympia, Washington, this _______ day of _____________, 199__

APPENDIX 4-3

Commercial, Industrial Agreement
to Maintain
Stormwater Management Facilities
and to
Implement
A Pollution Prevention Plan

Olympia, Washington

Drainage Design and Erosion Control Manual for Olympia, Washington

Commercial, Industrial Agreement to Maintain
Stormwater Management Facilities and to Implement
A Pollution Prevention Plan

The upkeep and maintenance of stormwater management facilities and the implementation of pollution prevention plans is essential to the protection of aquatic resources. All property owners are expected to conduct business in a manner that promotes resource protection. This Agreement contains specific provisions with respect to maintenance of stormwater management facilities and use of pollution prevention practices.

LEGAL DESCRIPTION:

Whereas, Business Name, has constructed improvements, including but not limited to, buildings, pavement, and stormwater management facilities on the property described above. In order to further the goals of the Jurisdiction to ensure the protection and enhancement of Jurisdiction's aquatic resources, the Jurisdiction and Business Name hereby enter into this Agreement. The responsibilities of each party to this Agreement are identified below.

BUSINESS NAME SHALL:

1. Implement the stormwater management facility maintenance program included herein as Attachment "A". (maintenance checklist similar to that developed in Chapter 7)

2. Implement the pollution prevention plan included herein as Attachment "B". (parking lot maintenance, covering outdoor storage areas, etc.)

3. Maintain a record (in the form of a logbook) of steps taken to implement the programs referenced in (1) and (2) above. The logbook shall be available for inspection by Jurisdiction staff at ____________________ during normal business hours. The logbook shall catalog the action taken, who took it, when the action was done, how it was done, and any problems encountered or follow-on actions recommended. Maintenance items ("problems") listed in Attachment "A" shall be inspected on a monthly or more frequent basis as necessary. Business Name is encouraged to photocopy the individual checklists in Attachment "A" and use them to complete its monthly inspections. These completed checklists would then, in combination, comprise the monthly logbook.

4. Submit an annual report to the Jurisdiction regarding implementation of the programs referenced in (1) and (2) above. The report must be submitted on or before _________ of each calendar year and shall contain, at a minimum, the following items:

   A. Name, address, and telephone number of the business, the person, or the firm responsible for plan implementation, and the person completing the report.
   B. Time period covered by the report.
   C. A chronological summary of activities conducted to implement the program referenced in (1) and (2) above. A photocopy of the applicable sections of the logbook,

with any additional explanation needed, shall normally suffice. For any activities conducted by paid parties not affiliated with Business Name include a copy of the invoice for services.

D. An outline of planned activities for the next year.

THE JURISDICTION SHALL:

1. Provide technical assistance to Business Name in support of its operation and maintenance activities conducted pursuant to its maintenance and pollution prevention control programs. Said assistance shall be provided upon request, and as Jurisdiction time and resources permit, at no charge to Business Name.

2. Review the annual report and conduct a minimum of one (1) site visit per year to discuss performance and problems with Business Name.

3. Review this agreement with Business Name and modify it as necessary at least once every three (3) years.

REMEDIES

1. If the jurisdiction determines that maintenance or repair work is required to be done to the stormwater management facility existing on the Business Name property, the Jurisdiction shall give the owner of the property within which the facility is located, and the person or agent in control of said property, notice of the specific maintenance and/or repair required. The Jurisdiction shall set a reasonable time in which such work is to be completed by the persons who were given notice. If the above required maintenance and/or repair is not completed within the time set by the Jurisdiction, written notice will be sent to the persons who were given notice stating the Jurisdiction's intention to perform such maintenance and bill the owner for all incurred expenses. The Jurisdiction may also revoke stormwater runoff utility rate credits for the quality component or invoke surcharges to the quantity component of the Business Name bill if required maintenance is not performed.

2. If at any time the Jurisdiction determines that the existing facility creates any imminent threat to public health or welfare, the Jurisdiction may take immediate measures to remedy said threat. No notice to the persons, listed in (1) above, shall be required under such circumstances.

3. The owner grants unrestricted authority to the Jurisdiction for access to any and all stormwater management facility features for the purpose of performing maintenance or repair as may become necessary under Remedies (1) and (2).

4. The persons, listed in (1) above, shall assume all responsibility for the cost of any maintenance and for repairs to the stormwater management facility. Such responsibility shall include reimbursement to the Jurisdiction within 30 days of the receipt of the invoice for any such work performed. Overdue payments will require payment of interest at the current legal rate for liquidated judgments. If legal action ensues, any costs or fees incurred by the Jurisdiction will be borne by the parties responsible for said reimbursements.

5. The owner hereby grants to the Jurisdiction a lien against the above-described property in an amount equal to the cost incurred by the Jurisdiction to perform the maintenance or repair work described herein.

This Agreement is intended to protect the value and desirability of the real property described above and to benefit all the citizens of the Jurisdiction. It shall run with the land and be binding on all parties having or acquiring from Business Name or their successors any right, title, or interest in the property or any part thereof, as well as their title, or interest in the property or any part thereof, as well as their heirs, successors, and assigns. They shall inure to the benefit of each present or future successor in interest of said property or any part thereof, or interest therein, and to the benefit of all citizens of the Jurisdiction.

Agreed to and signed by:

____

Owner Date

STATE OF WASHINGTON, COUNTY OF THURSTON

On this day and year, the above personally appeared before me and provided photo identification, and who executed the foregoing instrument and acknowledge that they signed the same as their free and voluntary act and deed for the uses and purposes therein mentioned.

Given under my hand and official seal this _____ day of _____________, 199__

Notary Public in and for the State of
Washington, residing in _________________
My commission expires _________________

Dated in Olympia, Washington, this _______ day of _____________, 199__

STATE OF WASHINGTON, COUNTY OF THURSTON

On this day and year, personally appearing before me, ______________________ and ______________________ , who executed the foregoing instrument and acknowledge the said instrument to be the free and voluntary act and deed of said Municipal Corporation for the uses and purposes therein mentioned and on oath states he is authorized to execute said instrument.

Given under my hand and official seal this _____ day of _____________, 199__

Notary Public in and for the State of
Washington, residing in _________________
My commission expires _________________

Dated in Olympia, Washington, this _______ day of _____________, 199__

APPENDIX 4-4

Standard Maintenance and Monitoring Agreement

BMP Facilities Maintenance/Monitoring Agreement

City of Alexandria, Virginia

City of Alexandria, Virginia

Standard Maintenance and Monitoring Agreement
BMP Facilities Maintenance/Monitoring Agreement

THIS AGREEMENT, made and entered into this __________ day of ____________, 19__, by and between ___________________________________, herein called the "Landowner" and the City of Alexandria, Virginia (the "City")

WITNESSETH

WHEREAS the Landowner is the owner of certain real property described _________________ as acquired by deed in the land records of the City of Alexandria, Virginia, Deed Book _______ at Page __________, hereinafter called the "Property".

WHEREAS, the Landowner is proceeding to build on and develop the property; and

WHEREAS, Plan of Development/Site Plan/Subdivision Plan __________________, hereinafter called the "Plan" which is expressly made a part hereof, as approved or to be approved by the City, provides for detention on-site treatment of stormwater runoff within the confines of the property; and

WHEREAS, the City and the Landowner, its successors and assigns agree that the health, safety, and welfare of the residents of the City of Alexandria, Virginia, require that on-site stormwater management facilities be constructed and maintained on the property; and

WHEREAS, the City requires that on-site stormwater management facilities as shown on the Plan be constructed and adequately maintained by the Landowner, its successors and assigns.

NOW, THEREFORE, in consideration of the foregoing premises, the mutual covenants contained herein, and the following terms and conditions, the parties hereto agree as follows:

1. The on-site stormwater management facilities shall be constructed by the Landowner, its successors and assigns, in accordance with the plans and specifications identified in the plans.

2. The Landowner, its successors and assigns, shall maintain the stormwater management facilities in good working condition, acceptable to the City, so that they are performing their design functions.

3. The Landowner, its successors and assigns, hereby grants permission to the City, its authorized agents and employees, to enter upon the property, and to inspect the stormwater management facilities whenever the City deems necessary. The purpose of the inspection is to assure safe and proper functioning of the facilities. The inspection shall cover the entire facilities, berms, outlet structures, pond areas, access roads, etc.

When deficiencies are noted, the City shall give the Landowner, its successors and assigns, copies of the inspection report with findings and evaluations.

4. In the event the Landowner, its successors and assigns, fails to maintain the stormwater management facilities in good working condition acceptable to the City, the City may enter upon the Property and take whatever steps it deems necessary to maintain said stormwater management facilities and to charge the costs of the repairs to the Landowner, its successors and assigns. This provision shall not be construed to allow the City of Alexandria to erect any structure of a permanent nature on the land of the Landowner, outside of an easement belonging to the City. It is expressly understood and agreed that the City is under no obligation to maintain or repair said facilities, and in no event shall this Agreement be construed to impose any such obligation on the City.

5. The Landowner, its successors and assigns, will perform maintenance in accordance with the maintenance schedule for the stormwater management facilities including sediment removal as outlined on the approved plans and the following specific requirements:

   For extended dry detention facilities, wet ponds, or infiltration facilities, insert the following:

   Maintenance of the (Insert type of facility) shall conform to the maintenance requirements contained in the Northern Virginia BMP Handbook published by the Northern Virginia Planning District Commission.

   For unconventional BMPs for which design criteria is provided in the Design Manual, insert the following:

   Maintenance of the (insert type of facility) shall conform to the maintenance requirements contained in Chapter 2 of the Alexandria Supplement to the Northern Virginia BMP Handbook.

   For unconventional BMP's not detailed in Chapter 2 of this manual and for experimental BMP's, insert specific maintenance requirements as approved by the Director of Transportation and Environmental Services prior to release of the Final Site Plan.

6. In the event the City, pursuant to this Agreement, performs work of any nature, or expends any funds in performance of said work for labor, use of equipment, supplies, materials, and the like on account of the Landowner's or its successors' and assigns, shall reimburse the City upon demand, within ______ days of receipt thereof for all costs incurred by the City hereunder. If not paid within such ______ day period, the City shall have a lien against the property in the amount of such costs, plus interest at the Judgment Rate, and may enforce same in the same manner as a lien for real property taxes may be enforced.

7. The Landowner, its successors and assigns, shall indemnify and hold harmless the City and its agents and employees for any and all damages, accidents, casualties, occurrences or claims which might arise or be asserted against the City for the construction, presence, existence or maintenance of the stormwater management facilities by the Landowner, its successors and assigns.

   In the event a claim is asserted against the City, its agents or employees, the City shall promptly notify the Landowners, their successors and assigns, and they shall defend, at their own expense, any suit based on such claim. If any judgment or claims against the City, its agents or employees shall be allowed, the Landowner, its successors and assigns shall pay all costs and expenses in connection therewith.

   The following additional paragraph shall be added for all agreements covering non-conventional or experimental BMP's.

8. The Landowner, its successors and assigns, hereby grants permission to the City, its authorized agents and employees, and to the Northern Virginia Planning District Commission, its authorized agents, employees and consultants, to enter upon the property, and to install, operate and maintain equipment to monitor the flow rate and pollutant content of the input flow, the effluent, and at intermediate points in the BMP. The Landowner further agrees to design and construct the facility to provide access for monitoring. The Landowner further agrees to a contribution of (as established during the Site Plan approval process ______ in the case of experimental BMP's) the entire cost of the monitoring program, payable prior to the release of the Final Site Plan, towards the cost of the monitoring program.

8. or 9. This Agreement shall be recorded among the land records of the City of Alexandria, Virginia, and shall constitute a covenant running with the land and/or equitable servitude, and shall be binding on the Landowner, its administrators, executors, assigns, heirs and any other successors in interests.

WITNESS the following signatures and seals:

____

(Landowner) (Seal)

By:____

____

Type Name

____

Type Name

ATTEST:

____

STATE OF __________________

CITY OF __________________

I, ______________________________, a Notary Public in and for the City and State aforesaid, whose commission expires on the _______ day of ________________, 19___, do hereby certify that ______________________________ whose name(s) is/are signed to the foregoing Agreement bearing date of the _______ day of _____________, 19___, has acknowledged the same before me in my said City and State.

GIVEN UNDER MY HAND THIS ______ day of ___________________, 19___.

____
NOTARY PUBLIC

WITNESS the following signatures and seals:

____
Director, Department of T & ES (Seal)

By: ____

____
Type Name

____
Type Name

ATTEST:

____

STATE OF __________________

CITY OF __________________

I, ______________________________, a Notary Public in and for the City and State aforesaid, whose commission expires on the _______ day of ________________, 19___, do hereby certify that ______________________________ whose name(s) is/are signed to the foregoing Agreement bearing date of the _______ day of _____________, 19___, has acknowledged the same before me in my said City and State.

GIVEN UNDER MY HAND THIS ______ day of ___________________, 19___.

____
NOTARY PUBLIC

APPENDIX 4-5

RECOMMENDED MAINTENANCE
OF
STORMWATER MANAGEMENT SYSTEMS

EXAMPLE OF LANGUAGE
INCLUDED IN
STORMWATER NPDES MS4 PERMITS
ISSUED IN FLORIDA

Chapter 5
Maintenance Considerations For Facility Owners

1. OVERVIEW

Of all the individuals, groups, and agencies that influence or participate in the maintenance of a stormwater management facility, the facility's owner has by far the most powerful and direct role. The owner's maintenance action (or inaction) not only affects the facility itself, but also strongly influences the actions (or reactions) of others. However, facility maintenance is only one of many activities and responsibilities vying for the owner's attention. As a result, facility maintenance is sometimes overlooked, neglected, or abused by the owner. Furthermore, as the complexity of a facility's ownership increases from a single to multiple and even corporate ownership, or ownership is conveyed over time to a series of new owners, the potential for oversight, neglect, or abuse also increases. This can lead not only to a failure to achieve expected or required facility performance levels, but can also threaten peoples' health, safety, property, and their water bodies.

Perhaps the power and influence of stormwater management facility owners can best be summarized in the following observations. ***At their best, stormwater facility owners can form the solid foundation of a successful stormwater management program, providing leadership to regulators and program managers, motivation to facility planners, designers, and maintainers, and security to fellow community members. Conversely, at their worst, facility owners, through neglect and disinterest, can mislead, discourage, and threaten these very same people, thereby undermining the stormwater management program and fostering mistrust and cynicism of its goals and importance***.

1.1. Objectives

To advance the Handbook's overall goal of effective and efficient facility maintenance and to avoid the grave consequences described above, the objectives of this Chapter will be:

- To explain the full meaning of stormwater management facility ownership.
- To educate stormwater facility owners about the purpose, goals, and operation of stormwater management systems.
- To present an overview of the mechanical, hydrologic, and biological processes by which stormwater facilities fulfill their purpose.
- To describe the potential hazards inherent in stormwater management systems by virtue of these characteristics and the potential liabilities inherent in facility ownership.
- To demonstrate to facility owners the importance of responsible maintenance in minimizing and managing these hazards and liabilities.
- To define the scope and content of a responsible facility maintenance program.

- To assist and encourage facility owners in establishing and conducting maintenance programs.

1.2 Intended Readers

Intended readers of this Chapter include:

- **Single, multiple, and corporate owners** of both onsite and remote site facilities. This includes present facility owners as well as those who may or will become owners in the future.

- **Public officials** who are responsible for developing, promulgating, and/or operating stormwater management programs and overseeing facility performance, maintenance, and safety. These officials will find valuable insights into the duties, demands, and liabilities of facility ownership that should be useful in creating more effective and successful programs.

- **Facility planners and designers** who should also view stormwater management facilities through the eyes and budget of their owners, an experience that should motivate them to include the minimization and ease of maintenance as a primary design goal.

2. THE MEANING OF STORMWATER MANAGEMENT FACILITY OWNERSHIP

Perhaps the best way to begin a discussion of such a philosophical topic would be to describe how and why someone, some group, or some organization becomes the owner of a stormwater management facility. This can best be described by explaining how and why stormwater facilities have come to be part of an owner's property or project in the first place. Next, a discussion of basic facility operation and components will help explain why stormwater facility maintenance is both necessary and important to the owner. Finally, this discussion will also explain how these maintenance needs and priorities may vary depending the type of facility and how the owner must identify and respond to the particular needs and priories of their own facility.

The productive use of land for agriculture, industry, commercial enterprise, recreation, and governance has been a cornerstone of civilization since ancient times. As populations grew and social needs and interests expanded, the development of land for these purposes also grew. In many ways, the modern land developer, redeveloper, or owner is satisfying many of the same societal needs for housing, employment, and material goods as explorers, traders, and pioneers have done in past centuries.

Since the middle of this century, however, many of the adverse impacts of land development and land use change have come into clearer focus. Two of the most pervasive are the effects they have on the quantity and quality of stormwater runoff. As land is converted from a natural, undisturbed condition to a man-made one, a process which usually includes the elimination of indigenous vegetative cover, the regrading of the land surface, the addition of buildings, roadways, and other impervious surfaces, and the installation of more efficient stormwater drainage systems, the quantity and velocity of runoff that will flow from a parcel of land onto downstream properties and waterways can increase by several hundred percent. These increases can create new, and severely aggravate existing, flooding and erosion problems on these downstream areas. In addition, by introducing into the runoff the by-products of the new land use, including the emissions and drippings from vehicles, industrial processes, power generation and waste disposal, and the solid and liquid wastes generated by the land's inhabitants and users, the runoff's chemical and biological quality can be dramatically reduced.

The rewards and penalties for developing and changing land use has presented society with a dilemma. While society's growth needs cannot be ignored, neither can the harm caused by our attempts to meet those needs through continued land development and redevelopment. How can this dilemma be resolved?

One possible method or technique is the creation and use of stormwater management practices, which are physical devices or facilities designed and constructed as part of the land development process to address the adverse runoff quantity and quality impacts described above. While there are several types of stormwater management facilities (see **Chapter 1 - Introduction** for definitions of the primary facility types contained in the Handbook), most facilities accomplish their stormwater management goals through a few fundamental processes. These processes were discussed briefly in **Section 3 of Chapter 2 - Stormwater Pollutants and Reduction Mechanisms** and are further described below.

2.1. Basic Stormwater Management Facility Operation

As noted above, the adverse impacts of land development or redevelopment can be an increase in the rate, volume, and speed of the runoff from the development site during a storm event. In order to prevent these increases from creating or aggravating flooding or erosion problems downstream, all or a portion of the site's runoff can be conveyed to a stormwater management facility. During periods of excessive runoff (that could cause downstream problems if it had not been constructed), the stormwater management facility will temporarily store this excess runoff within its storage area while, at the same time, discharging only a portion of the runoff through its outlet structure at a nonharmful rate.

This rate, which is sometimes established by the government agency having jurisdiction over the land development, may be equal to the rate of runoff that flowed from the site prior to its development. In other instances, particularly where there are known flooding or erosion problems downstream or where detailed engineering analyses of the downstream waterways or the entire watershed have been performed, the outflow rate considered or specified to be "nonharmful" may at times be even less than the predeveloped rate. Nevertheless, the outflow rate can be seen to be a function of both the size of the facility's storage volume and the hydraulic characteristics of its outlet structure. ***Thus, the size and characteristics of storage volume and outlet structure will, in turn, be dependent upon the amount of excessive runoff created by the development*** or, in other words, the difference in the runoff amounts from the site under predevelopment and post-development conditions. This is one reason why some development projects will require large stormwater management facilities occupying considerable amounts of land, while others will be able to accomplish the same stormwater management goals with less extensive facilities occupying much smaller areas.

In order to prevent or at least mitigate some of the harmful runoff quality impacts of the land development project, stormwater management systems may employ a variety of techniques to either remove some of the harmful pollutants from the runoff or to treat or convert them to less harmful forms. ***Many of the pollutants will settle to the bottom of the facility by gravity if the runoff is left in the facility's storage area for a long enough time. This requires careful discharge of the runoff from the storage area in order to prevent short-circuiting of the pollutants through the storage area or resuspension of the pollutants from the bottom after they have settled***. Other removal techniques include passing the runoff through filtering media such as sand, peat, or dense vegetation that removes certain pollutants by blocking their passage. Other practices use vegetation to actually absorb some of the runoff and pollutants into the plants through their root systems, where they are stored or converted by the plants' biological processes. Finally, some stormwater management facilities will enhance the natural removal and/or conversion processes described above through the controlled addition of chemicals or the use of mechanical treatment devices.

2.2. Stormwater Management Practices

As noted above, the characteristics of both the site and the downstream waterways can affect the required storage volume and land area of a stormwater management facility. However, facilities may vary in several other ways, including the location and nature of the storage area and the characteristics and behavior of the facility's outlet. All of these variations will create different maintenance demands that the facility owner must respond to. A review of these variations should help owners to better identify, understand, and respond to the maintenance demands of their own facilities.

For example, the storage areas of most stormwater management systems are located above the ground surface, where they can be readily inspected and accessed by maintenance personnel and equipment. However, due to site constraints, some stormwater facilities are located below ground in tanks or chambers, where access and mobility is much more restricted. In addition, some facilities may only detain incoming runoff during and immediately after a storm event, while others may retain some water permanently, creating a lake or pond that is present under both wet and dry weather conditions. As defined in **Chapter 1 - Introduction** and described in detail in **Chapter 2 - Stormwater Management Practices**, such facilities are designated as either ***dry or wet detention practices***, depending upon whether they are normally dry or wet during nonrainfall periods.

Detention practices, whether wet or dry, discharge their runoff onto downstream areas through an outflow structure, which may include orifices, weirs, pipes, and channels. However, stormwater facilities defined in Chapter 1 as ***infiltration (or retention) practices may not have formal outlet structures***. Instead, they discharge their runoff through the soil which surrounds the bottom and/or sides of the facility's storage area.

As noted above, there are several different techniques by which runoff pollutant loadings are reduced by a stormwater management facility. These include settlement by gravity in detention practices and a combination of settling, evapotranspiration, and percolation through the ground in infiltration practices. Other facilities defined in Chapter 1 as ***filtration practices force runoff to flow through beds of sand, peat, or even compost to remove pollutants, while facilities defined as biofiltration practices use dense stands of vegetation or other organic media***. Finally, it is important to note that many stormwater management facilities have the physical and operating characteristics of several different practices, particularly with regards to stormwater pollutant removal, and therefore cannot easily be categorized. ***Additionally, many stormwater systems may include a combination or series of facilities or practices***.

A final characterization is important. Since the runoff quantity impacts of land development or redevelopment (i.e., volume, rate, and/or velocity) have been recognized for a much longer period of time than the runoff quality impacts, many older stormwater management facilities were designed and constructed to only address these quantity impacts. In recent years, however, the runoff quality impacts of land development/redevelopment have gained considerable attention and, in some instances, even priority over the quantity concerns, resulting in the use of facilities for runoff quality control only. ***Therefore, it becomes necessary at times to designate whether the type of facility under consideration is intended for runoff quantity or quality control purposes. This will be done in the Handbook by adding either word to the facility type (e.g., a "quantity detention facility" or "quality infiltration facility")***. When neither word is added, the reader can assume that the facility is intended to address both stormwater management impacts. Finally, facility types such as filtration or biofiltration facilities are only intended to address runoff quality impacts and, therefore, no additional description is necessary. Detailed information regarding the various stormwater management practices included in this manual is presented in **Chapter 2**.

2.3. Stormwater Facility Components

Just as different stormwater management facilities may employ different storage, outflow, and pollutant control mechanisms, there are different functions assigned to each area or component of a facility. ***To help facility owners better understand the characteristics and operation of their own facilities, thereby enhancing their ability to identify and respond to their unique maintenance requirements, a description of the major components of most stormwater management practices is presented in Table 5-1***. As discussed below, each of the components described in the table not only have different functions, characteristics, and locations within a stormwater management facility but, by virtue of these attributes, also have different maintenance needs and priorities.

In reviewing the table, it is important to note that not all facility types have all components. For example, since an infiltration facility discharges its outflow through the surrounding soil, it will may not have a principal outlet structure, especially if it is an off-line facility. Similarly, a vegetated swale or filter strip, which controls runoff quality by filtering runoff at shallow depths through dense vegetation, will not normally have a principal outlet structure, dam, or trash racks. In addition, since some stormwater management systems display the characteristics of many facility types, the list of components presented in the table should not be considered exhaustive. Finally, the component descriptions have been developed specifically for this Handbook. As such, different or additional descriptions may be used in other publications.

2.4. Operational Impacts on Facility Maintenance

It should be apparent by now that stormwater management facilities achieve their assigned stormwater management goals through a wide variety of means and techniques and, as such, each may consist of a similarly wide variety of components and characteristics. It is also important for facility owners to recognize that, due to these facts, ***each type of facility has its own unique maintenance demands and priorities***. For example, an infiltration facility, which will discharge its runoff through the surrounding ground, will require more frequent removal of sediment and small debris than a dry detention facility, whose outlet structure will allow a much greater portion of the incoming sediment and small debris to pass through. This is also true of a wet detention facility, where a greater amount of sediment and debris will be captured and retained in the permanent pool than the normally dry bottom of the detention facility.

Further comparisons will also be useful. For example, while both infiltration and wet detention facilities will capture and retain a

Table 5.1.

Major Components of Stormwater Management Practices

COMPONENT	DESCRIPTION
PRINCIPAL OUTLET	Hydraulic structure that controls and conveys the facility's outflow to the downstream conveyance or receiving water.
EMERGENCY OUTLET	Hydraulic structure or spillway that safely conveys emergency overflows from the facility. Includes approach and exit channels.
DAM/EMBANKMENT	Wall or structural fill that impounds runoff in the facility above the adjacent ground surface.
BOTTOM	The lowest or deepest surface within the facility.
SIDE SLOPES	Slopes at dams, embankments, spillways, and facility perimeters constructed through excavation or filling.
TRASH RACK	Device placed upstream of the principal outlet or drain to intercept trash and debris that would otherwise block it.
LOW FLOW SYSTEM	Surface and/or subsurface measures that convey low and dry weather inflows to the principal outlet without storage.
INLETS	Upstream surface and/or subsurface conveyance measures that discharge runoff into the facility.
OUTFLOW SYSTEMS	Downstream surface and/or subsurface conveyances or water bodies which receive facility outflows from the principal outlet.
PERIMETER	Area immediately adjacent to the facility.
ACCESS SYSTEMS	Measures and devices that provide maintenance personnel and equipment access to various facility components.
VEGETATIVE COVER	Vegetation planted on various facility components to stabilize their surfaces and/or provide stormwater treatment.
BYPASS SYSTEM	A system which allows a facility owner to temporarily bypass the stormwater facility to allow a maintenance activity to occur in the "dry".

greater portion of the inflow's sediment and debris than a dry detention facility, the presence of the wet basin's permanent pool will normally make it much more difficult, time-consuming, and expensive to remove sediments than the normally dry bottom in the infiltration facility. In addition, the removal of sediments from a properly constructed wet detention pond typically is only needed every 10 to 15 years, while an infiltration facility often requires annual removal. Finally, it can be seen that since a stormwater facility intended to address both runoff quantity and quality impacts will, by its nature and operation, capture and retain more sediment than a quantity-only facility, it will also require more frequent sediment removal efforts.

In addition to the varying maintenance needs of different stormwater management facilities, it can also be seen that ***different facility components will also impose different maintenance demands on the facility owner***. For example, trash racks, low flow channels, and adjacent areas of the bottom will collect more sediment and debris than emergency spillways, side slopes, dams, and other components and will, therefore, require more frequent and thorough cleaning. Conversely, the structural integrity of dams, embankments, emergency spillways, and outlet structures are, relatively speaking, more vital to the safety of the facility and downstream areas and, therefore, will warrant more thorough inspection and more immediate repair than low flow channels, perimeters, or bottoms.

It is important that stormwater management facility owners understand these distinctions and comparisons, for it is through such understanding that owners can more effectively and economically allocate their maintenance resources and meet their maintenance responsibilities. This is particularly true where such resources are limited due to economic, personnel, or equipment constraints. It is also true for potential facility owners such as land developers, home buyers, and commercial or industrial leasees, who must plan and budget for facility maintenance as part of their overall operations. Failure to do so can be disastrous, as described in the following section.

2.5. The Impacts of Facility Maintenance Neglect

When the maintenance of a stormwater management facility is neglected, the immediate impacts can quickly escalate into serious health and safety problems. Immediate impacts typically include a decline in the facility's appearance, which can adversely impact the overall aesthetic character of the surrounding area. Such impacts may be severe to some owners, particularly if the area's appearance is vital to its economic or social vitality. Examples of such instances include office sites, shopping malls, and commercial buildings that need to attract and keep tenants and customers, and residential neighborhoods that want to sustain both their quality of life and high property values.

Other impacts from initial maintenance neglect can include the creation of nuisances at the facility, including odors, mosquitoes, and habitats for mice, rats, and other vermin. All of these can once again adversely impact the site's aesthetic character, and potentially adversely impact on site property values. They will also reduce the quality of life and may create health and safety threats to workers or residents in the immediate area.

If the neglect continues, the facility's ability to perform its intended functions will begin to be impaired. This can have several serious and escalating impacts. For example, if the facility is intended to provide stormwater treatment, a reduction in this treatment can result in ecological damage to downstream water bodies. If the facility has been required as part of a site discharge permit or land development approval, these impacts may also have serious legal consequences. If the facility is intended to prevent excess runoff from leaving the site, downstream flooding or erosion may occur. This will not only physically threaten downstream property owners but will pose serious legal and liability problems for the neglectful facility owner.

Finally, the maintenance neglect can reach such a level that dams and embankments begin to weaken and structures become unstable. At this point, the facility has become a direct threat to the health and safety of the people that live or work both at and downstream of the facility. This is particularly true if the facility impounds a significant amount of water which can suddenly be released without warning and with disastrous effects on downstream properties.

As shown above, ***many of the adverse effects of facility maintenance neglect will be felt by someone other than the facility's owner***. This is unfortunate since, as described above, these are the people that the facility was built to protect. As such, it can be seen that any harm caused to these people or their property due to facility maintenance neglect can be the strong basis for a negligence lawsuit against the owner, particularly if it can be demonstrated that the owner willingly neglected the facility's maintenance despite the knowledge that such neglect could be harmful. Such a lawsuit may be further strengthened by the fact that the owner derives most, if not all, of the benefits provided by the facility, and not the downstream residents or owners that are threatened by the neglect or malfunction.

The exact extent of an owner's liability for damages arising from facility maintenance neglect will vary from state to state and will depend, in part, upon the exact type of facility in question. In general, however, two legal concepts may by applied, particularly if the facility impounds a body of water and is legally considered to be a dam. Under the legal concept of negligence, the degree of care exercised by the owner would be a factor in determining the owner's liability for any damages that might have occurred due to facility failure. Under the legal concept of strict liability, however, the facility owner would be held liable for any damages that occurred due to facility failure regardless of the cause of that failure. In either case, it can be easily seen that ***stormwater management facility ownership involves a significant degree of legal responsibility for regular and thorough facility maintenance and operation***.

In addition to the adverse physical and legal impacts of maintenance neglect, the neglected facility that fails to meet outflow quality or quantity requirements or safety standards may place its owner in violation of local, state, or federal discharge regulations. Such violations may subject the owner to fines, sanctions, and/or the loss of operating or occupancy permits. They will also undermine the stormwater management programs upon which the regulations are based and reduce the overall effectiveness and credibility of local, state, and federal stormwater management programs. Chronic and widespread neglect can even threaten the existence of such programs. As such, it can be seen that t***he facility owner also has a civic responsibility to conduct a regular and thorough stormwater facility maintenance program***.

Finally, neglect of a stormwater facility's maintenance can have severe economic impacts for its owner over and above any fines, legal judgements, settlements, and attorney fees. This is due to the fact that ***the cost to perform facility maintenance on a regular basis can be several times less than a one-time cost to restore a long-neglected facility to normal or required condition***. For example, a program of grass mowing and sediment and debris removal performed regularly at a dry detention facility may only require a few man-hours per month using only lawnmowers, shovels, and wheelbarrows. On the other hand, if such activities where neglected for a protracted period of time, the effort to restore the facility to its normal condition can require considerably more effort, money, and equipment.

In summary, there are many legal, economic, civic, and ethical impacts that await the owner of a neglected stormwater facility. These impacts should be sufficient reason for all owners to establish and conduct a regular and thorough facility maintenance program. Details about such a program and the resources that will be required to develop one are presented below.

3. TYPES OF FACILITY OWNERS

It can be seen from the above that there are many different types of stormwater management facilities controlling the quantity and/or quality of stormwater runoff. As such, it is not surprising that there are many different types of facility owners. Since each type of owner will have somewhat different operating procedures, resources, organizational structures, and legal standing and authority, each type will have to take somewhat different steps to develop and conduct a stormwater management facility maintenance program. Therefore, it will be helpful to review the basic categories and types of facility owners.

The three basic categories of facility owners include private, public, and joint public-private ownership. Private owners include individuals, partnerships, corporations, and cooperative associations. Public owners include municipalities, counties, states, authorities, utilities, and federal agencies. Joint ownership may exist in certain instances, particularly where one party owns the facility (including the land it is located on) and the second party is responsible for its maintenance. Such arrangements are common between municipal or county governments, which are responsible for the maintenance of a facility, and residential, commercial, or industrial site owners who own the property on which the facility is located.

In the case of private ownership, it can be seen that the resources, organizational structure, and legal standing of a private individual will be considerably different from a corporation. For example, the individual can be held personally responsible for the maintenance of a facility and personally liable if damage occurs to offsite property or third parties due to maintenance neglect. A corporation may only be liable for the assets of the corporation, thereby protecting the individual shareholders. An individual owner can also be expected to be more directly involved in the actual maintenance activities, be more readily engaged in evaluating program performance, to act more quickly to remedy problems, and more flexible in addressing changes in operating procedures. However, the individual can also be expected to have fewer resources to perform facility maintenance at their disposal and less ability to raise additional capital to finance facility maintenance or repairs.

Similarly, a municipal government may be more directly involved in facility maintenance activities than its state or federal counterparts and have greater flexibility to address changes and problems. However, the municipality may once again have less overall resources at its disposal. All levels of public ownership can be expected to have less options for financing than private owners and will not be able to address changes in maintenance costs as easily or quickly. Public bidding and purchasing laws and annual budget cycles may further limit a public owner's financing and operating options.

The overall operating experience and capabilities of the owner will also directly effect their ability to adequately perform facility maintenance. For example, a municipal or county government whose public works department regularly maintains open spaces, recreational facilities, and structures will be better prepared to develop and conduct a facility maintenance program than a homeowners association or a commercial building owner. Perhaps the owner best suited to perform facility maintenance is the stormwater utility or authority which has been established for stormwater management purposes and vested with its own financing capabilities.

Finally, studies and experience have shown that ***while all types of owners may neglect facility maintenance, the likelihood of such neglect increases with the size and complexity of the ownership organization***. This is due, in part, to the more vague, diffuse, and even fractured designation of maintenance responsibility within the larger organization, the ability of the organization to monitor the performance of its members, and its ability to quickly respond to problems and adopt new procedures where necessary.

In summary, a successful maintenance program will require the facility's owner to have some level of organizational and management skills, legal counsel, financial resources, emergency response capabilities, maintenance equipment and personnel, and a basic understanding of facility operation and associated government regulations. In developing and then conducting a successful facility maintenance program, it is important for the owner to objectively identify and evaluate their strengths and weaknesses in these areas. This will enable the owner to realistically determine what program components they can best perform and which ones will be better performed by contractors or consultants. It will also help potential owners to evaluate the implications of facility ownership prior to assuming ownership responsibilities, so that appropriate prior arrangements can be made or ownership can either be shared with another party or avoided entirely.

4. MAINTENANCE PROGRAM DEVELOPMENT

While the details of a maintenance program for a specific stormwater management facility will be somewhat unique, there are general steps that most if not all facility owners can follow. Details of each are presented below. In many instances, additional information regarding specific aspects of each step can be found in other sections of this manual. When this is so, the specific section will be noted.

4.1. Designate a Responsible Individual

As noted above, the potential for facility maintenance neglect typically increases with the size and complexity of the organization that is responsible for the maintenance. Therefore, ***a key step in developing a successful facility maintenance program is to designate a key individual within that organization to be personally responsible for the program's overall performance***. It is not necessary for this person to actually participate in the various maintenance tasks, although a working knowledge of these tasks based upon personal experience is certainly preferable. The responsible individual must, however, have some direct role in managing and supervising the maintenance activities. The selection of this individual should be based upon several factors. Since the individual owner is the simplest ownership organization possible, the choice of who that individual should be is obvious. However, as the size of the ownership organization increases, the choice may not be so obvious and each of the selection factors warrants careful consideration and evaluation by the owner.

The choice of responsible individual should be a function of the person's experience, expertise, and position of responsibility within the organization. Typically, this position should be low enough to allow the person to have a significant degree of direct, personal involvement with the overall maintenance program, particularly its personnel and the various tasks they perform and equipment they use. However, the position must be high enough within the organization that the responsible individual has the authority to effectively manage the program and can command the attention of people higher up when necessary, particularly in regard to program funding.

Since the responsible individual will, indeed, be held personally responsible within the ownership organization for facility maintenance, they must be granted sufficient authority over personnel, procedures, and expenditures to achieve the success they're held accountable for. Optimally, this includes the authority to identify tasks, establish relevant policies and procedures, hire, fire, and assign personnel, delegate authority, and establish priorities.

The responsible individual should also have a basic understanding of stormwater management facility function, operation, and construction as well as an understanding and appreciation for the physical, social, regulatory, and legal implications of facility ownership and maintenance. This understanding should also extend to knowing when outside technical, physical, or legal assistance is needed to fill a gap in organization's in-house expertise or ability.

Finally, since the responsible individual will often be acting as a liaison between such diverse groups as maintenance personnel, upper management, residents, customers, government regulators, and contractors, good communication skills will also prove highly valuable.

4.2. Plan for Maintenance

A successful facility maintenance program does not happen by chance. Instead, a responsible facility owner will plan and budget for maintenance, not merely perform it. Such planning should obviously be performed as far in advance as possible of actually beginning the maintenance work, a recommendation that should not be lost on those potential or pending facility owners who are looking to develop or purchase a site with a stormwater management facility. Such planning should include several program aspects:

1. **Identify Facility Characteristics and Maintenance Needs** - As detailed above, each type of stormwater management facility has some physical, functional, and operating characteristics that are unique and, as such, each will have certain distinct maintenance needs. For example, a wet detention basin or pond intended to provide both runoff quantity and quality control will have largely different maintenance needs than a subsurface sand filter intended to provide only runoff quality control. The basic understanding of stormwater management facilities advocated earlier in this chapter will serve an owner well at this stage of the maintenance planning process.

   This ***identification process can begin with a list of all types of onsite facilities that the owner will be responsible for maintaining***. Based upon each type, the basic operating characteristics and maintenance needs can then be determined. If possible, particularly for new facilities, the owner should consult with both the facility's designer and constructor to help identify these characteristics and needs. For new facilities, the owner should make sure that the designer will include maintenance as one of their primary design considerations. Further information regarding the design aspects of facility maintenance can be found in **Chapters 2 and 3** of this Handbook.

2. **Identify Regulatory and Legal Requirements** - In many instances, the stormwater management facility will have been designed and constructed to meet regulatory constraints placed upon the development and/or use of the property. These regulations may have been in the form of an approving resolution from a local or county planning board or an actual facility operating permit issued by a regional, state, or federal agency. In many jurisdictions, the owner will have been required to sign a maintenance agreement with the approving authority guaranteeing adequate facility maintenance and granting that authority certain inspection rights. ***In order to be both thorough and efficient, the maintenance planning process should identify all relevant requirements in such approvals, agreements, and permits, which should then be evaluated for their impacts on facility maintenance***. Further information regarding the regulatory and administrative aspects of facility maintenance can be found in **Chapter 4**. While written primarily for regulators and administrators, this chapter can provide owners with valuable insight into this important aspect of facility maintenance.

   In addition to regulatory requirements, the owner should also review the legal implications of facility ownership, particularly in regard to facility maintenance and the legal impacts of its neglect. This should include both the legal impacts of violating agreements, permits, and other regulatory controls as well any physical harm caused to onsite workers, residents, customers, tenants, and/or downstream individuals and entities. In many instances, such a review not only helps to define the tasks and resources necessary for the maintenance program but also serves as a strong incentive for conducting it successfully.

3. **Define Maintenance Tasks, Personnel, and Equipment** - Once the physical, operational, and legal needs are determined, the actual maintenance tasks and their associated personnel and equipment needs can be defined. Such tasks may range from simple grass mowing and periodic debris removal, to sediment testing and removal, to aquatic plant habitat and wildlife management. Details of the various maintenance tasks required at different types of stormwater facilities can be found in **Chapter 7**.

   In addition to direct maintenance tasks, the need for periodic inspections of the facility should be included in the planning process. Since the exact success or frequency of an individual maintenance task cannot be determined prior to its execution, it will be necessary to inspect the facility periodically to assess whether the selected procedures and their frequency are adequate. Even when they are, facility operating conditions can still vary considerably over a time period and the maintenance program will be constantly subjected to dynamic forces. As a result, the inspection program must continue throughout the facility's life if the program is to remain both effective and efficient. Details of a comprehensive maintenance inspection program are also presented in **Chapter 7**.

4. **Establish Schedules -** Since successful facility maintenance is an ongoing process, schedules must also be established. These include such obvious items as the frequency of the various maintenance tasks identified in Step 3 above. Since conditions at the facility may vary greatly over the year, the need to periodically change the type and frequency of maintenance tasks should not be overlooked. Facility inspection schedules must also be established. In addition, all regulatory reporting schedules required as part of an operating permit or other approval condition must also be determined. Some facilities may also require a formal inspection by a licensed engineer or other professional on an annual or biannual basis.

   Finally, funding availability will normally be affected by budgetary cycles or accounting periods. As such, it will be necessary to ***determine how frequently different expenditures will be required so that they can be scheduled and coordinated with their associated funding process or mechanism***. Such expenditures may range from daily or weekly expenses for fuel and material to monthly invoices from outside contractors to annual equipment upgrades. Provisions should also be made for funding emergency repairs and for such typically infrequent and/or irregular tasks as pond desilting. In addition, the frequency of any regulatory costs such as inspection fees or permit renewal fees should also determined.

5. **Establish Record Keeping Procedures** - Due to the nature of stormwater management facilities in general and the specific tasks necessary for their maintenance, ***a record of past maintenance efforts and the results of past inspections can greatly assist the continued effectiveness of the maintenance program***. For example, such records can be used to identify chronic maintenance problems that can be addressed more effectively through a new piece of equipment or change in procedure. They will also be extremely useful at budget preparation time when past costs need to be justified and new ones need to estimated and funded. Finally, comprehensive maintenance and inspection records may prove invaluable if the owner and/or the maintenance program is challenged legally by a plaintiff or regulatory agency.

4.3. Identify Costs and Allocate Resources

Prior to this step, which may be considered the most important step of any facility maintenance program, the necessary maintenance tasks and their associated equipment, personnel, and frequency should have been determined along with the facility's regulatory and legal obligations. Based upon this information, the costs of these various items and the overall cost of the maintenance program should be estimated. Once determined, the source(s) of the necessary funding must be identified and secured.

The importance of identifying costs and funding sources in a facility maintenance program cannot be overestimated. In most instances, experience has shown that the maintenance of a stormwater management facility does not, in general, require extraordinary levels of effort or expertise on the part of the maintenance personnel, nor specialized or exceptionally sophisticated equipment to assist them. As such, these are usually not the predominant factors associated with the failure or ineffectiveness of a facility maintenance program. Instead, such results are more likely to be simply a lack of adequate program funding, which can occur due to a lack of prior planning by the owner. ***In summary, adequate and stable funding is, in most instances, the most important key to maintenance program success***.

4.4. Create a Written Plan

Once the maintenance program and its funding have been developed, it is important that it be formalized in a written document. The exact format or level of sophistication of the document are not as important as the actual existence of the document in written form. In written form, it will be much easier to 1) understand and appreciate the overall scope of the program and all its facets, which can be particularly helpful for funding, budgeting, and regulatory purposes; 2) establish a coordinated and effective implementation plan of all those facets; 3) establish performance goals that people, especially the designated responsible individual, will be held accountable for; 4) conduct periodic program reviews (see Section 4.5 below); 5) describe and justify the scope and intent of the program in case of legal challenge.

The written plan should include:

1. The name of the current responsible individual.
2. The names and/or positions of the various maintenance staff members and, if helpful, an organization chart.
3. A list of all facilities maintained by the program along with their location, type, and other pertinent details.
4. A list and description of each of the identified maintenance and inspection tasks.
5. Lists of all required and available equipment and material.
6. All regular inspection and maintenance schedules.
7. Copies of the pertinent sections of all regulations, permits, approvals, and agreements.
8. Copies of maintenance and inspection logs.
9. An "as constructed" plan of the facility.

The written plan should also include or reference other pertinent facility information such as design computations, construction and as-built plans, emergency action plans (where required or developed). A list of off-hour telephone or pager numbers of key maintenance personnel should also be included in case of emergencies. See **Chapter 7 - Inspection and Maintenance after Construction Completion** for more information.

There should be at least two identical copies of the maintenance plan. The owner of the facility must have one of the plans while the agency responsible for stormwater program implementation or maintenance inspections should have the other. If a third entity assumes maintenance responsibility on behalf of the owner, that entity must also have a copy.

The maintenance plans should be located where they can be referred to as the need arises. The public agency should have a permanent file system where all maintenance plans reside and are available for public review. The owner's plan should be placed with other important property information, and reviewed at least on an annual basis to ensure that the plan is in good condition and accurately reflects ongoing efforts.

4.5. Conduct Periodic Program Reviews

As noted above, both a stormwater management facility, and the program established to maintain it, will be subjected to constantly changing forces and factors. With the facility, these will include variable climatic and rainfall conditions, development and maturation of vegetation, wear and impacts on structures and linings, and even vandalism. With the program, these will include changes in personnel, cost increases due to inflation, new or revised regulatory programs and permit conditions, new equipment, material, or maintenance techniques, or internal management or ownership changes. As such, ***a successful facility maintenance program must include a regular process of review and evaluation***.

Such reviews can begin with the effectiveness and efficiency of the various maintenance tasks, including an evaluation of personnel expertise and experience and equipment performance. The program's ability to meet maintenance and reporting schedules should also be reviewed. Costs should also be tracked and evaluated to determine if rising trends can be reversed or cost savings can be realized. In this instance, such a review may best be held prior to the start of the organization's budgetary cycle.

A comprehensive program review will revisit past problems to determine what their cause was and how they might be prevented or corrected more effectively and/or efficiently. This may include an assessment of how the facility's design and/or construction may be causing the problem and how changes to these procedures may eliminate similar problems at future facilities.

In conducting the program review, it may also be productive to evaluate whether an internal maintenance program may be more effectively or efficiently performed by outside contractors. Conversely, services presently provided by such contractors should be compared with those that could be provided by in-house personnel and/or equipment. Finally, the legal environment and regulatory conditions under which the program must function should be periodically reviewed to identify necessary or helpful changes to reduce legal exposure or to comply with new regulations, laws, or permit conditions.

Chapter 6
Construction Inspection

1. OVERVIEW

Plan design and review, construction inspection, maintenance inspections, and owner/operator understanding of obligations are essential components of successful implementation and long term performance of stormwater facilities. A breakdown in any of these areas will cause premature failure of the BMP. The best design plan has no value if the facility is not constructed according to the design. ***Construction inspection determines, to a very large extent, the frequency that subsequent maintenance is needed on a given facility.*** The use of poor quality materials for construction, and poor construction in general, can negate all of the time and effort expended during the design phase.

Stormwater facilities are constructed by individuals having a wide range of experience in their construction. Individuals with little experience constructing BMPs need assistance in knowing what to look for and what components are essential for quality control of construction. Even individuals having significant experience in BMP construction often need assistance due to changes in site conditions upon which the design was based, or where a modification to the design would improve facility construction and maintenance. The most important individual in these situations is the construction inspector.

The construction inspector interacts with the site contractor and the plan approval agency. The inspector is vital in assuring proper construction and links the overall process from design through construction. The contractor is independently retained by the site developer and generally has no input into the actual design of the stormwater facility. He is hired for construction and must review the approved plans and specifications and determine the best construction method to fit the site and approved plans. It is not his role to question design assumptions or recognize that an approved plan will not necessarily result in the best approach to site management from a stormwater management standpoint. ***The construction inspector, through his interaction with the plan approval agency and experience in stormwater management, assumes that role.***

Problems associated with poor stormwater BMP construction range from minor to major. Minor problems can include partial clogging of infiltration practices, premature maintenance needs related to sediment removal, replacement of a system component such as riprap, mosquito breeding, slope erosion, or standing water in a facility not designed to have it. Major problems could necessitate replacement of the entire facility, structural repairs, or safety concerns. ***It is easier and more cost effective to build a stormwater facility right the first time than to have to remobilize construction equipment to repair the facility on a premature basis.*** In addition, the quality of reconstruction often means that the level of expectations must be reduced from the initial design assumptions. For example, an infiltration basin, prematurely clogged with fine sediments, will probably never achieve design infiltration rates due to the presence of an increased level of fine particles in the bottom and sides, even with excavation of the finer sediments. Proper construction of stormwater facilities will have a significant beneficial impact on future maintenance costs.

Construction inspection can be broken down into several components which together provide for effective implementation of stormwater facilities. The inspection components include:

- a clearly defined legal authority,
- preconstruction activities,
- inspection during construction,
- construction site inspection procedures, and
- short term post-construction inspection responsibility to determine stormwater facility bond release approval.

Quality of construction affects more than the long term stormwater management system performance. Facility construction can also have a direct impact on receiving systems, especially when problems are encountered during their construction. Proper inspection is needed to reduce downstream impacts of the construction process itself. The last section of this chapter is devoted to discussing ways to reduce pollutant discharge, primarily of sediments, impacts on receiving systems.

It should be recognized that the discussion provided in this chapter and elsewhere is devoted to general activities which are associated with urban runoff control. Where a specialized activity exists, such as control of industrial runoff , then individual consideration of the types and quantities of pollutants expected and their potential adverse impacts on the stormwater BMP must be done.

1.1. Intended Readers

In attempting to achieve a "minimum maintenance" stormwater system, construction inspection is often one aspect of a project that does not receive the attention it deserves from owners, project managers, and government officials. With that thought and the objectives discussed above in mind, those who will benefit most from this Chapter include:

- **Project and Construction Managers**, who should view construction inspection as a vital quality control measure that is in the best interests of all those concerned with the creation of a stormwater management system.

- **Construction Inspectors**, who should clearly understand their project responsibilities and the specific tasks that are critical to achieving the intended design.

- **Contractors**, who should realize that proper construction inspection will help avoid construction problems and delays and assure both quality workmanship and rapid completion.

- **Code officials**, who should fully understand the important role they must play in achieving a high quality, minimum maintenance stormwater facility.

Additionally, several other readers can benefit from this Chapter including:

- **Planners, Designers, and Project Reviewers**, who should be aware of the value of proper construction inspection while preparing or reviewing construction plans, specifications, and other contract documents.

- **Project Managers**, whose responsibilities include providing assurance that the project will be constructed to the best possible standards.

- **Stormwater System Owners**, who should realize that it is in their long term interest to create the highest quality facility and thereby avoid unnecessarily high OMM costs in the future.

2. STORMWATER SYSTEM CONSTRUCTION IMPACTS AND MITIGATION

The impacts associated with construction of stormwater management systems are very similar to those occurring from general site construction activities. A major difference is that erosion and subsequent sedimentation from general construction may not result in all sediment leaving a site. Sediment may travel for a distance down a slope and then deposit itself in an area that promotes sedimentation of the suspended particles. Construction of stormwater management systems, especially ponds, generally occur in low areas of a construction site. Wet ponds often are located in a ravine or incised area adjacent to a perennial stream where the delivery of sediments is unbuffered by downstream areas of deposition. In addition, stormwater management system construction occurs where concentrated flow of runoff from upstream drainage areas accelerates the uplift and transport process of soils and sediments generated by the dam construction.

The proximity of the stormwater system construction to major stream systems and defined floodplains typically results in delivery of the sediments into environmentally sensitive areas. Also, high stream flow may inundate the facility construction area causing scour and excessive sedimentation. It is important for an inspector to realize the sensitive nature of construction impacts of stormwater facilities. They are placed on sites to reduce environmental impacts, but their construction may have a significant impact if good site control is not provided. ***During an inspection, the inspector must carefully consider the potential impact of stormwater system construction on downstream sensitive areas.***

The impacts of sedimentation off-site and downstream can be classified into two categories of impacts: Economic and Environmental.

2.1. Economic Impacts of Sedimentation During Stormwater Management Pond Construction

The displacement and transport of sediments into stream systems will create negative impacts from several perspectives. The most traditional and clearly understood economic impacts are those resulting from sedimentation to navigable waters, especially in estuaries, and to increases in the risk of flooding. Because of sedimentation, dredging of channels and boat docking areas is needed more frequently, thereby increasing the cost of maintenance dredging and sediment disposal.

Flooding and out-of-channel storm flow may increase due to sediment deposition within channels and floodplain areas. Maintenance is a significant responsibility where flood control channels have been constructed previously. In these situations, flood protection is provided through channel storage and conveyance. Sedimentation of the channel reduces its' cross-sectional area, and its ability to provide the desired level of flood protection. Another flood related impact occurs when nontidal wetlands are smothered. The wetlands vegetation, due to its dense growth, serves as a buffer during runoff events, providing flood storage and retarding flood flows. This reduces velocities of stormflow and helps provide additional flood protection to downstream areas.

Economic impacts are incurred in association with impaired function of culverts and pipes downstream from construction activities. These conveyance systems rely on the cross-sectional area of the pipe or culvert to convey the design storm flow. Sedimentation of culverts or pipes reduces their storm flow conveyance capacity. This may lead to increased road flooding, increased flooding on properties upstream of the road crossing, or increased risk of flooding downstream if the road embankment fails due to water pressure or scour.

Another economic impact of sedimentation is related to the loss of biological resource productivity. Shellfish beds and fish eggs are smothered by sediment. Also, fish can't see food which also affects the resource. A significant commercial or sporting industry can be and has been reduced by sedimentation.

2.2. Environmental Impacts of Pollutant Discharge During Construction

In addition to strict economic impacts, stormwater system construction can cause environmental impacts. From a water quality perspective, there are a many pollutants that may be generated at a stormwater system construction site. The first and most obvious pollutant is sediment. Many other types of pollutants adhere to sediment and get transported downstream. Toxic metals are inert by nature, and many bind strongly to sediments. Control of sediment will, to some degree, control the migration of other pollutants.

Other types of construction generated pollutants are present on stormwater management facility construction sites. These pollutants are associated with motor vehicle equipment operation and commonly include the constituents listed in Table 6-1. They accumulate on construction sites and can migrate downstream causing impacts to aquatic resources. These other pollutants include organics and inorganics, nutrients, construction debris, pesticides and herbicides, and bacteria.

The health of a stream ecosystem depends largely on its benthic community. Sediment smothers aquatic organisms, upon which larger species feed. Thus, the loss of the benthic organisms reduces the stream's capability to sustain larger organisms. Experience has shown that the single largest, long term impact on a stream ecosystem results from excessive downstream sedimentation during site development. It may take years for a partial recovery of the stream system to occur.

TABLE 6-1. POLLUTANTS GENERATED BY CONSTRUCTION MOTOR VEHICLES

Pollutant	Automotive Source
Asbestos	clutch plates, brake linings
Copper	thrust bearings, bushing, and brake lining
Chromium	metal plating, rocker arms, crankshafts, rings, brake linings
Lead	leaded gasoline, motor oil, transmission babbitt metal bearings
Nickel	brake linings
Phosphorus	motor oil additive
Zinc	motor oil and tires
Grease and hydrocarbons	spills and leaks of oil and lubricants, antifreeze and hydraulic fluids
Rubber	tire wear

Beside the environmental impacts to stream ecosystems, other environmental impacts are associated with wetland loss and degradation. Wetlands provide significant water storage and pollution removal. Filling wetlands, as a result of construction sedimentation, reduces their ability to store floodwaters and remove pollutants. Wetlands also provide habitat for wildlife. As wetlands are filled by sediments, its habitat is destroyed and its wildlife value is reduced.

It is also important to note that there are other secondary, but lesser understood, impacts associated with toxics carried by stormwater. These potentially can disrupt the food chain. Uptake of toxic substances by micro- and macro-organisms can lead to bioaccumulation and biomagnification as the toxic substances are ingested by higher organisms in the food chain. Little is known about the actual processes and levels of impact associated with stormwater toxics, although shellfish beds have been closed to harvesting. Additional work is needed in this area to more accurately determine their impacts.

3. LEGAL AUTHORITY FOR INSPECTIONS

Stormwater management construction inspectors must have adequate legal authority, from state or local laws or regulations, to inspect and enforce the program's construction requirements. Outlined below is an example of legal authority for construction inspections adapted from the Prince George's (MD) Department of Environmental Resources Stormwater Management Design Manual:

1. Inspectors must conduct inspections and file reports for periodic inspections, as necessary, during construction of stormwater facilities to assure compliance with the approved plans.

2. Inspectors are authorized to furnish the permittee or agent the results of the inspection in a timely manner after the completion of each required inspection.

3. Inspectors are authorized to issue a Correction Order to the permittee or agent when any portion of the work does not comply with the approved plans.

4. Inspectors are authorized to issue a Notice of Violation in accordance with guidelines as a result of unsatisfactory work or progress.

5. They are authorized to issue Stop Work Orders as the result of unsafe conditions, working without a permit, unsatisfactory work, progress, or other noncompliance.

6. Inspectors are authorized to issue a Civil Citation as a result of unsafe conditions, noncompliance with a Stop Work Order, unsatisfactory work, progress or other noncompliance.

7. Inspectors are authorized to perform a final inspection upon the completion of the stormwater facility to determine if the completed work is constructed in accordance with the approved stormwater design plan, approved "as-built" plan and certified by the permittee's registered professional engineer.

8. Inspectors are authorized to inspect the stormwater facility at a specified post-construction time to determine release of the maintenance performance bond.

The authority to accomplish these functions should be provided in law, ordinance, or resolution. This provides the inspection program with the necessary "teeth" to ensure that stormwater systems are constructed in accordance with the approved plan. A variety of enforcement options should be available, as one option may be more effective than another in a particular situation. It is also important that the enforcement aspect of program implementation be progressive. The intent should be that minor enforcement actions are generally attempted first, with more serious action being reserved for those situations where there is a knowing and willful violation. There must be an ability and willingness to take aggressive action when it is required.

Having the legal authority to take enforcement actions does not necessarily mean that they will be taken. Too many programs have excellent legal authority for enforcement actions, but staff are seldom allowed to take actions necessary to improve site implementation of stormwater controls. This is especially a problem when inspections necessitate additional expenditures to correct problem areas, or where necessary site controls have not been constructed. This especially is a problem for erosion and sediment control practices, but is also a serious concern for the construction of permanent stormwater facilities.

The stormwater program must make a commitment to allow its staff to conduct site inspections and take necessary enforcement action when it is needed. This is not to suggest that enforcement action can be taken whenever desired - only that it is available as an option to assure compliance. Senior agency staff must be briefed when a particularly aggressive action is intended, but day-to-day enforcement actions must be endorsed by the appropriate jurisdiction to ensure continuity of program implementation and to ensure that stormwater facilities are given the best opportunity to perform to design standards for the longest possible time.

4. PRECONSTRUCTION ACTIVITIES

An approved stormwater management permit may be transferred to the responsible inspection agency for construction inspection. The inspector has two primary functions at this stage of project implementation - review of the approved plan, and a preconstruction site meeting.

4.1. Review of Approved Stormwater Management System Plan

The construction inspector should review the approved stormwater management plan to become familiar with the requirements placed upon the land developer. This review should include the following items:

A. The overall site development proposal and site conditions,

B. Location of the stormwater management facility, erosion and sediment control plan, and site grading plan,

C. Location of storm drain system,

D. Dimensions, as specified, are shown on approved plans,

E. Potential problem areas with construction that may require special attention,

F. Any special approval conditions,

G. Specifications for construction materials,

H. Shop drawings, where needed,

I. Sequence of construction (may be a requirement of plan approval or submitted by contractor prior to work initiation), and

J. Any easements or site areas having restrictions placed upon them such as wellhead protection areas or natural wetlands.

It is important that the inspector completely understand all aspects of the approved stormwater control plan, especially its structural practices and their components. If there are any questions, the inspector should contact the plan review and approval agency and receive answers to any concerns or questions. If the construction inspector is unsure of any aspect of the construction, it can almost be a certainty that the contractor will also have misunderstandings. Communication between the plan review agency and construction inspector is essential so that each can understand the perspective of the other.

One helpful approach is to have the plan review individual highlight on the plans erosion and sediment control and stormwater management BMPs or make special notes to emphasize these items to the inspector. If this cannot be done, the inspector should highlight them.

This helps to assure they have a high visibility during future inspections. It also highlights them from other special notes that tend to be on construction drawings.

Shop drawings should be submitted for all stormwater management system components. Shop drawings should include methods of construction, as well as detailed specifications of the materials. Problems can be avoided if potential areas of ambiguity are resolved before facility construction. A situation which should be avoided is an on-site confrontation between the inspector and contractor over some material specification that was not considered before construction. Having shop drawings available for the preconstruction meeting helps reduce potential areas of disagreement. Often a contractor's bid to do work is based on the cost of materials that the contractor commonly uses. Changes to these commonly used materials may increase project costs and cause problems between the land developer and the contractor. ***By resolving potential conflict areas before construction, the quality of construction can be enhanced and potential conflicts reduced.***

4.2. Preconstruction Site Meeting

It is important to meet with the owner, contractor, project engineer, and any other site related inspectors to establish a dialogue and line of communication. Other individuals having roles in the stormwater facility construction also should be included, especially subcontractors and utility companies. Preconstruction meetings also let the owner and contractor know what aspects of the stormwater system construction are in need of the most attention. This meeting also establishes the inspection agency's importance and priority on proper construction. Items which should be discussed at the preconstruction meeting include:

A. Telephone numbers (during and after work) of the different individuals in the event of the need to communicate.

B. Recognition that the approved plans must be on site whenever there is construction.

C. The project's overall purpose and objective.

D. Specific areas where stormwater facility details need to be emphasized or which require special attention.

E. Construction sequences, schedules, and timetables.

F. A chain of command in the event that field modification or changes needs to be made.

A detailed list of recommended preconstruction meeting topics is summarized in Appendix 6-1 at the end of this chapter.

5. INSPECTION RESPONSIBILITIES DURING CONSTRUCTION

There are a number of specific responsibilities the inspector must assume during construction. These can be broken down into two areas: routine inspection responsibilities and activity-specific inspections.

5.1. Routine Inspection Responsibilities

Routine inspections are important to gauge the progress of site development and to assess the quality of construction. ***These inspections help ensure that the developer/contractor is aware of the inspector's periodic presence onsite. Routine inspections also demonstrate the importance the implementing jurisdiction places on the adequacy of stormwater system construction.***

As stated in Chapter 4, it is important that the land developer/contractor closely coordinate and communicate with the inspection agency. This is especially true when scheduling inspections. Generally, at least 24 hours notice is needed. Inspections and inspector approval of work must be completed at the critical stages of stormwater management system construction. The actual notification of the inspection agency by the land developer at critical times may not always occur, and routine inspections are one way to assess timetables. They also provide an opportunity for the inspector to remind the contractor of the need for inspections at specific times during construction of the stormwater management system. Regardless, ***it is important for the contractor/developer to recognize the need to contact the inspector when certain stages of construction are reached.*** This is already recognized in other aspects of construction, such as electrical or plumbing inspections. The stormwater inspection agency needs to stress to the contractor the importance of scheduling inspections at important stages of construction. The agency must also convince the land developer/contractor that the inspections are in their best interest.

When routine inspections are accomplished, their results must be documented, preferably with standardized inspection forms. Examples of a Routine Inspection Form and a Notice to Comply Inspection Form are provided in Appendix 6-2. ***Inspection forms provide a consistent record of site inspections and establish a framework for inspection and enforcement activity.*** The results should then be provided to the contractor, transmitted to the developer, and also placed in the project's inspection file. This documentation of the inspection results provides feedback to the contractor and developer on the adequacy of erosion and sediment control BMPs and overall facility implementation at various stages of construction. ***Too often, inspectors visit a site, do not notify any site personnel, and leave no record of their inspection. This approach may reduce confrontation, but provides limited benefit to any individual other than the inspector.***

The inspection form details site conditions to the contractor/developer and provides a barometer of any site inadequacies which may need to be addressed. In addition, if site construction is proceeding according to the approved plan, it also notifies the contractor/developer that they are doing a good job. ***Positive feedback is as important as criticism. There are many times when the contractor/developer goes beyond the letter of the law and is extremely conscientious in their efforts. These efforts should be recognized in the inspection report.***

A program may want to use several different inspection forms. The first inspection report should be used to assess general site conditions while the second form would be used to require site correction or compliance according to an administrative order. The routine inspection form can be used when the site is generally in compliance or where minor corrections need to be made to achieve compliance. The Notice to Comply or Correction Notice establishes necessary site improvement conditions and time frames. The Notice to Comply establishes a formal paper trail of progressive enforcement. The goal is to improve site conditions and achieve compliance with approved plans.

5.2. Progress Meetings

In addition to periodic routine inspections, regular progress meetings should be held to discuss construction timetables, problems, needed changes to the approved plans, and ensure coordination between the land developer, contractor, and inspector. This inspection is primarily a meeting between the various parties as opposed to a site inspection to assess progress of the stormwater management system construction. The stormwater management approval engineer should attend these meetings to provide insight into the appearance, essential components, and any other aspect of the facility design which needs to be emphasized.

Extra work and needed change orders are the primary items discussed at these progress meetings. These changes will occur on all construction activities, as detailed design review and approval cannot anticipate all possible site conditions that may be encountered during construction. The inspector and, where appropriate, the design review engineer should carefully evaluate each extra work charge and change order to ensure its legitimacy. Recommendations on their acceptance must be timely. Unnecessary delays in resolving problems can result in poor relationships, poor construction quality, and unnecessary extra construction costs. Costs for the design and implementation of stormwater management systems is a great concern to everyone. Realistic costs have to be defended and expected, but unnecessary costs must be avoided. Many excessive costs can be avoided if there is effective communication during construction of stormwater management systems.

The progress meeting provides a number of benefits other than assuring proper construction. By having periodic interaction between all of the parties involved, all individuals gain a greater understanding of why these facilities are necessary, how construction needs to be accomplished, and a greater appreciation regarding the relationship between design and construction. This is very true of the plan approval engineer. Too often, these individuals become overwhelmed with the plan review function, and do not get the necessary experience in actual construction of stormwater management systems. Familiarity with construction could have a significant impact on their plan review and approval activities. The progress meetings also ensure that the developer and contractor are constantly aware of their obligations and are giving them frequent consideration.

5.3. Final Inspection

A final inspection should be required prior to the contractor being allowed to demobilize equipment from a site. This inspection should be linked with granting occupancy permits or other required final approvals. As recommended in Chapter 4, the stormwater management system bond should not be released at this time. The bond should extend for a specific time frame (warranty period typically one year) to ensure short term performance of the facility.

Any incomplete items associated with the stormwater management facility should be detailed in this inspection and provided as a specific "punch" list to the contractor and developer. A time frame for correction of the listed items should be decided upon so that a reinspection can be scheduled at the appropriate time.

This inspection is critical to the long term performance of the stormwater management system. ***Final approval of a site should not be given until all deficient items have been corrected.*** When the site receives final approval, the public and eventual site users or owners have an expectation of construction adequacy. It is important that every possible step has been taken to reduce their future expenditures for operation, maintenance, and management of the stormwater facility.

6. INSPECTION PROCEDURES

Consistent, meaningful inspection procedures are essential to effective site implementation and success of the stormwater management program.

6.1. Have Necessary Inspection Equipment

Equipment, which should be included in an inspector's inventory, includes the following:

- A Locke level or other surveying equipment
- Local erosion and sediment control or stormwater management handbooks.
- Rain and foul weather gear.
- Copies of necessary inspection reports and forms.
- Business cards or other means of identification.
- A camera to document field conditions in the case enforcement action becomes necessary.

Other equipment may be desirable, but is not considered essential, such as a vehicle telephone that allows an office supervisor to be contacted for guidance on what to do in a given situation.

6.2. Check In At The Construction Trailer

Too often, inspectors visit a site and do not stop in at the trailer prior to conducting their inspection. Many times, a contractor will want to conduct a site inspection with the inspector. This joint inspection can provide an opportunity for the inspector to provide some educational tips to the contractor which may preclude future problems. In addition, the contractor doesn't want unauthorized people walking around the site. Recognition by the contractor that the inspector is on site will allow he or she to continue with their activities and not stop what is being done to inquire why the inspector is on the site.

6.3. Always Complete An Inspection Form and Give to the Contractor/Developer

Documentation of site conditions, both good and bad, provides a feedback loop to the contractor and developer about their efforts at construction of erosion and sediment controls and stormwater management facilities. ***An inspection report does not have to only discuss problem areas of the site. They should also be used for acknowledging good efforts, where the developer can recognize contractor activities.*** Good inspection reports can provide the contractor with positive feedback, and prove a valuable record for future inspections. If a new or different inspector visits the construction site and provides a different emphasis or evaluation, the previous positive inspection report can demonstrate the intent to comply with permit requirements.

Inspection forms also provide the basis for any necessary enforcement action. By documenting problems and corrective measures, the inspector provides the "paper trail" for legal action, should it become necessary. The forms can provide site documentation to supervisory individuals and they also provide a measure of the inspectors' work load.

6.4. Generally Speaking - Always Walk the Site in a Consistent Manner

The stormwater program should establish a specific protocol by which inspections are done. For example, always start at the site entrance and proceed in clockwise manner around the site. This allows the contractor, another inspector, or any other individual to easily follow the notation used in an inspection report. This is especially important on larger sites, where there are numerous environmental controls. Being able to follow previous inspection comments can reduce the time needed to conduct inspections, especially follow ups on a previous inspector's comments and concerns.

6.5. Wear Safety Equipment, such as Safety Glasses, Hard Hat, and Steel Toed Shoes

All individuals at a construction site must meet minimum safety standards. The contractor is often reluctant to correct an inspector on necessary safety equipment, but is still liable for ensuring that all site personnel wear the necessary equipment. ***Wearing safety equipment, proactively, can reduce the number of adversarial issues and demonstrate the inspectors' respect for contractor obligations and site standards.***

7. INSPECTOR ATTITUDES AND TRAINING

Inspectors are often placed in a difficult confrontational position with a developer, contractor, and possibly even with their own supervisory or plan review staff. The type of individual best suited for this job would benefit by having the following attitudes. Each of these attitudes and training is important individually, but all are necessary if the individual is going to be successful in their role as an inspector.

- **Confidence**

  Inspectors are frequently confronted with reasons why a facility cannot be constructed according to the plan or why erosion and sediment control strategies cannot be implemented according to the approved plan. The inspector must have the confidence to deal with these situations and be sure of the necessary responses to each situation. At times, the correct response is to discuss the specific issue with a supervisor or the appropriate plan approval individual.

  Regardless, inspectors must feel comfortable with their experience and knowledge of the construction industry to recognize the validity of a specific issue or problem. There will be times when an inspector must insist on site modification or compliance, even if it results in a confrontational situation. The inspector cannot be the contractor's best friend. There will be situations where a hard line must be taken. Inspectors must have confidence in their actions.

- **Interest in the function**

  In too many situations, the erosion and sediment control and stormwater management inspector has been given the function for a reason other than the individual's interest in erosion and sediment control and stormwater management. In these situations, expectations for adequate construction and maintenance must be lowered. The inspector must recognize their importance to the program's overall goals and success.

  Being a regulatory program inspector requires more than experience in construction. The position is difficult when adversarial roles are established or when hearings, court cases, or meetings are held where the inspector's actions are held under a microscope. The inspector must accept these varying responsibilities and want to do the job.

- **Experience with construction**

  Inspectors must recognize the real world impact of their requirements on site. There should be an awareness of the capabilities of various types of construction equipment, and of which equipment may be inappropriate for a given function. There is a cost associated with equipment and the inspector must recognize these costs when establishing site needs and time frames.

  It is important for the contractor to recognize that the inspector does have an understanding of site work and time frames. In the same regard, knowledge of construction will allow the inspector to recognize when a contractor is giving an excuse for noncompliance rather than expressing a real problem. ***Contractors quickly recognize how much latitude they can get from an inspector. Their recognition of an inspector's awareness of proper construction practices will have a positive impact on site implementation of needed controls.***

- **Training needs**

The inspector is expected to deal individually with a wide range of people in the construction industry. Often the inspector is the only individual in a group on-site that represents the program's viewpoints. That individual must be trained and given the background to enable effective communication and actions to be taken. In Maryland, it was once estimated that approximately 18 months were necessary to adequately train an inspector. The first several months were spent instructing the individual about the program's goals, and it's commonly used individual practices, strategies, and facilities.

Then the training would include traveling around with experienced inspectors to learn how to conduct site inspections, what to look for on the plans and sites, and how to interact with construction-related personnel. Interaction with construction-related personnel is extremely important, since these interactions determine whether relationships are positive or negative. ***Inspectors must learn how to control their personal emotions and act in a professional manner on construction sites or the overall program may be adversely affected.***

- **Communication**

An inspector must interact with site personnel on a daily basis. Having an inspector who is a poor communicator results in misinformation or a lack of understanding by the contractor or developer on specific site concerns. Communication is an essential inspector function. The more effective the ability to communicate, the more potential exists for good site implementation of erosion and sediment control and stormwater management controls.

- **Commitment**

Commitment means accepting limited resources, having too large a work load, periodically disagreeing with developers and contractors, and accepting that what they are doing is important. An adage located in the Sussex County Conservation District, Sediment and Stormwater Program Inspection Office (Delaware) clearly states their feelings on inspection:

:

"Arguing with an inspector is like wrestling with a pig in the mud, after a while you realize that the pig enjoys it"

Anti-seep collars, barrel, and riser assembly for a stormwater management detention basin.

8. INDIVIDUAL BMP INSPECTION CONSIDERATIONS

The two site inspection forms in Appendix 6-2 are used for general site construction. They are very appropriate for erosion and sediment control inspection and can be used for stormwater management system construction inspection. However, they must be augmented by inspection checklists specific to each type of stormwater BMP. These checklists highlight critical construction details that need inspection to assure stormwater management system construction is in accordance with the approved plans. They should accompany the project file. They can assist the inspector determine when specific sites should be inspected and what components of the stormwater system may require more individual attention and consideration.

Several components of stormwater systems may not be visible if inspections are not done when these parts are being installed. Examples include core trenches for ponds, anti-seep collars or diaphragms, compaction of embankments, filter fabric for infiltration facilities, etc. It is vital that an inspector ensure that these essential parts are installed or constructed as the approved plans detail. Otherwise, there is a risk that an important component is constructed poorly or even omitted.

Routine inspections are needed to determine site progress, however, stormwater practices have unique elements which require individual attention. Specific inspection needs associated with each type of stormwater management practice will be discussed individually in this section. Detailed facility inspection forms are included in the appendices of this chapter.

The following discussions of individual practices are separated into two areas: Design Considerations and Construction Considerations. Important aspects in each category are discussed from an inspector's perspective. Communication with the plan approval agency is especially important during design discussions. If the items discussed are not detailed on the approved plans, the inspector should contact the plan approval agency to determine the reason for an item's omission. ***Communication is the cornerstone to proper stormwater system implementation.***

8.1. Detention and Retention Systems

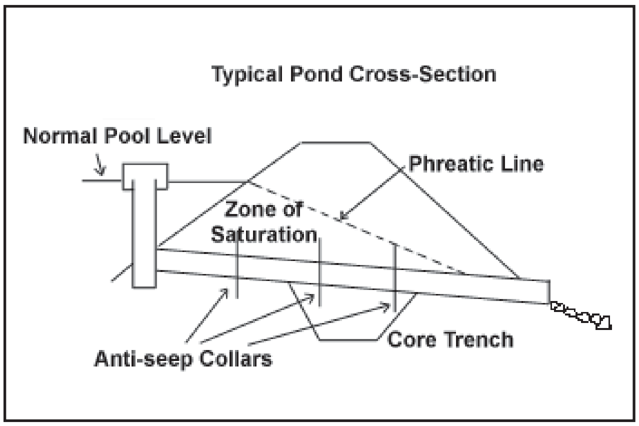
Detention and retention systems vary in many ways. Retention and dry detention practices are normally dry, while extended dry and wet detention systems have a normal pool of water. Wet detention practices can be further subdivided into open water ponds and constructed wetlands. ***The inspection requirements for all of these practices will be summarized separately. Thereby, an individual needing specific information about a certain BMP can read only that discussion and get a comprehensive picture rather than looking in several places for pertinent information.***

Most of the information on wet systems is directed towards ponds where the normal pool of water is established by the construction of an embankment. Excavated ponds typically do not have the same safety concerns related to embankment failure. If unsure, the local Natural Resources Conservation Service can be contacted for technical assistance in determining whether a wet system is an excavated pond or an embankment pond.

8.1.1. Dry Detention Versus Wet Detention

The design and construction of these two types of detention practices is very similar. There is, however, one very big difference which is important to recognize for inspection purposes during construction. ***Detention ponds with a normal pool of water develop a zone of saturation through the embankment, which can***

increase failure potential in the future. Concerns regarding this zone of saturation (frequently detailed on plans as the area below the phreatic line) are alleviated by good quality control during construction. The risk of a potential hazard is reduced by requiring, during design, safety features in the embankment which reduce the movement of water through the embankment. These safety features include anti-seep collars, diaphragms, core trenches, and clay cores. These features are not visible once construction is completed. Their construction and quality of construction must be verified by the inspector during their installation. Failure to inspect these features at critical times may result in embankment failure in the future.



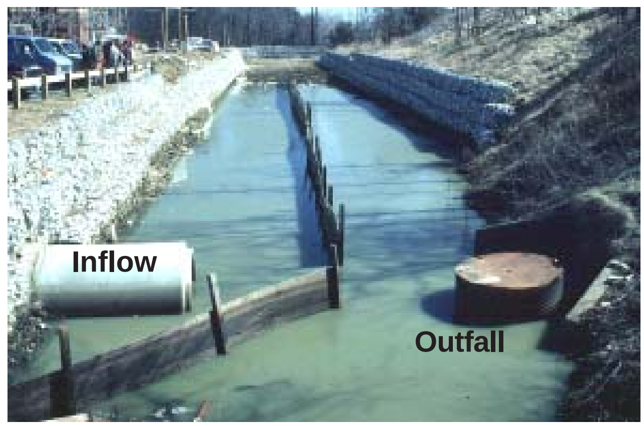
Detention or retention practices which are normally dry do not develop a zone of saturation (which results from standing water), and internal water seepage is not a critical concern. However, it is still important to have anti-seep collars or diaphragms even if embankment failure is not as important an issue.

8.1.2. Important Inspection Aspects Related to Design

When certain site conditions are encountered or where the design has an unusual aspect, it is important to communicate with the plan approval entity to ensure that a mistake wasn't overlooked. Examples of items which should be discussed include:

A. Encountering sandy soils when building a wet pond designed with a normal pool of water without a liner specified on the plans.

B. Stormwater inlets located adjacent to or near the intended outfall create a "short circuit" flow path. While this may be acceptable from a stormwater quantity perspective, the short circuiting will reduce treatment and lessen water quality benefits.



An example of a pond inflow point being close to the outfall.

C. Steep slopes into the pond with no slope breaks (benches) can increase the hazard potential and erosion of side slopes.

Steep side slopes at a dry pond. Note playground equipment at left top of slope.

D. Essential components normally associated with ponds are not included on the plans. These parts can include anti-seep collars, trash protection for low flow pipes, principal and emergency spillways.

E. Wet detention systems should have a means to draw the water level down should draining the pond become necessary. From an inspector's viewpoint, a detention pond design without a drawdown mechanism should be brought to the attention of the plan approval agency. Where ground water provides the permanent water pool, a drawdown mechanism won't be available. The inspector should know the expected or design ground water elevations at a site, especially the seasonal high level. This information should be contained on the approved plans.

Example of a pond failure due to piping adjacent to the principal spillway.

8.1.3. Important Inspection Aspects Related to Construction

This section highlights important aspects in the construction of ponds. Appendix 6-3 is an excellent example of a Sediment/Stormwater Management Pond Construction Checklist developed for the State of Delaware. This checklist, or a similarly adapted one, should be used by inspectors during construction of stormwater management ponds.

A. ***A major cause of detention and retention system failure is water traveling along the outside of the principal spillway. This is called piping.*** It generally occurs along a corrugated metal or concrete pipe. This piping of water, which is under pressure from the depth of water in the pond, causes erosion of soil adjacent to the pipe. Erosion of this material causes the pond embankment to be weakened at that point and failure of the embankment results. ***This failure is much more likely to occur in wet detention systems than in retention systems***. Detention ponds have a permanent pool of water next to the embankment. Water will soak into the embankment and seek a lower elevation. Failure potential can be prevented by proper installation of anti-seep collars or diaphragms, in conjunction with proper compaction of soils adjacent to the principal spillway and collars or diaphragms.

B. ***The general minimum standards for construction work also apply to the construction of stormwater systems.*** Does the construction comply with local material and equipment requirements for earthwork, concrete, other masonry, reinforcing steel, pipe, water gates, metal, and woodwork?

C. Are interior side slopes no steeper than 3-to-1(horizontal to vertical) and exterior side slopes no steeper than 2-to-1? The reason most stormwater embankment ponds remain stable is that the mass of earth in the embankment is heavy enough to prevent slippage of material caused by water pressure on the upstream slope. ***Steep side slopes are not only more dangerous to the general public, but they also reduce the total mass of earth material in the embankment. This can increase the potential for embankment failure***.

D. Are elevations relatively accurate and according to the approved plans? ***An inspector should carry a simple Locke level to determine whether a given location is at it's proper elevation***. The invert elevation of a principal spillway must be lower than the elevation of the pond embankment or trouble can be expected. A Locke level provides a quick, moderately accurate, means to verify field implementation.

E. Are inlet and outlet areas stabilized to prevent erosion? Relying only on vegetative practices for stabilization is generally inadequate since it takes time for the vegetation to become well established. Some form of additional stabilization technique is generally necessary to protect soil until growth of vegetation. This can include erosion control matting, riprap, gabions, etc.

F. Are safety features provided? These may include a shallow bench surrounding the pond edge, barrier plantings to discourage approach by children, and/or fencing where required.

G. A sequence of construction must be established and followed. ***It is just as important that construction be done in the correct order as having good quality construction.*** The sequence of construction includes preconstruction meetings, temporary erosion and sediment control, core trench, etc. An example of a typical pond sequence of construction is presented in Appendix 6-4.

Pond under construction.
Reverse slope bench above waterline and shallow slope in shallow water areas.

H. Upon completion of construction, a final inspection should be performed. This inspection provides written documentation to the developer/contractor of the satisfactory completion of the facility. Depending on local requirements, this inspection augments the submission of an "As-Built" Certification or Record Drawings.

8.2 Constructed Wetlands

Many parts of the discussion in Section 8.1 above also are applicable to constructed wetlands. This BMP often is considered a subset of wet detention systems. However, they merit their own separate section because of the complexities of their design and construction. Unlike wet ponds, constructed wetlands are shallow water systems that rely, to a very large extent, on the establishment and propagation of emergent wetlands plants to provide water quality benefits.

8.2.1. Important Inspection Aspects Related to Design

A. Clay or geotextile liners

The shallowness of wetland stormwater treatment systems means that even a small alteration in water level can significantly impact the health of the aquatic plant community. ***It is important to ensure that water levels remain somewhat consistent.*** This may necessitate the use of a clay or geotextile liner to maintain water levels. When reviewing approved plans, the inspector must determine how water levels in the constructed wetland are to be maintained. They may be maintained by continual stream baseflow, by high ground water levels, or by installation of a liner. ***The inspector must know prior to construction how water levels will be maintained***.

Geotextile liner for a constructed wetland.

B. Organic soil conditions

Wetlands are living systems with a wide variety of organisms, each of which requires sources of essential elements for growth and propagation. The most common way to provide these elements quickly is to place organic soils on the constructed wetland floor. The approved plans should specify any special provisions for placement of organic soils.

Organic soils are not always specified, but their inclusion is highly recommended to facilitate plant growth. Not having organic soils on the constructed wetland floor results in slower growth and spread of the wetland plants. It often also leads to the invasion by nondesirable aquatic plant pioneer species which can out compete more desirable plants.

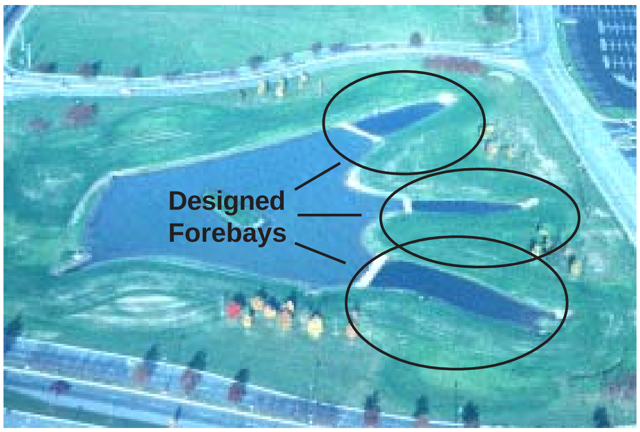
C. Shallow depth and slight grades

Unlike deeper detention systems, shallow constructed wetlands need to have exact grades in the inundated pool area. For the most part, constructed wetlands are dominated by emergent aquatic plants whose establishment and propagation typically depend on water depths under two feet. To have a diverse plant community, varying depths are needed since different plants are best suited for various water depths. The plans should detail design elevations throughout the ponded area where wetland plants will be established. They should also clearly identify where each type of plant should go.

D. Establishment of forebays

Being shallow water systems, constructed wetlands are very susceptible to filling in by sediments generated upstream. It is important that all principal inflow points be provided with forebays designed to trap the largest volume of suspended solids. ***Forebays provide a readily accessible location to allow***

periodic removal of accumulated sediments. Plans should detail the location, size, and proposed grades of designed forebay areas, along with dedicated access for maintenance equipment.



Detail of a constructed wetland showing designed forebays.

E. Concern regarding sediment entry into the system

Because they are shallow water systems, the long term performance of constructed wetlands can be significantly reduced by sedimentation. The approved plan should be reviewed to determine if the constructed wetland will be used as a sediment basin during the construction phase of the project. ***If used as a sediment basin, the plans should detail the conversion of the sediment basin into a constructed wetland***. If the constructed wetland is not used for sediment control, the plans should specify:

- Project phasing for overall site construction with a timetable for construction of the constructed wetland.
- How the constructed wetland will be protected from sediment entry when the drainage area is unstabilized.
- When sediment must be removed from the forebays or constructed wetland.
- That the wetland will not be planted until site stabilization is complete.

F. Reduced concern over saturated embankment problems

Most constructed wetlands have a shallow depth of water against the embankment. However, some wetland designs specify a deep water zone adjacent to the embankment. The shallow water reduces water pressure adjacent to the embankment and reduces the number of anti-seep collars needed to prevent piping along the principal spillway. The inspector should still expect to see at least one anti-seep collar on the principal spillway, but safety concerns are reduced compared to those that exist for deeper wet detention systems.

G. Reduced safety features

Deeper wet detention systems present other public safety hazards to those individuals living or working adjacent to them. ***Constructed wetlands present much less of a safety concern due to their denser vegetation, more gradual side slopes, and the shallow water depth.*** Plans, therefore, may not provide specific safety features.

H. Plant materials

Beside the water quality benefits resulting from detention time of stormwater within the wetland, water quality benefits also are provided by the wetland plant community, microbes, and the organic materials on the wetland's bottom. There are three approaches to establishing aquatic plants in constructed wetlands: plantings of aquatic plants which facilitates rapid plant growth; providing proper hydrology and soil conditions to promote colonization of the system by local vegetation; and installing soil having vegetative plant roots or rhizomes. Of course, these are not mutually exclusive, and proper conditions must be provided to sustain plantings.

The approved plan should detail which approach is used. If wetland plantings are to be used, the plan should specify:

- the plant species.
- the number of each species.
- where the plants will be located.
- if the pond water level will be lowered to facilitate planting.
- a timetable for planting to occur.

8.2.2. Important Inspection Aspects Related to Construction

A. If the constructed wetland is to be used as a sediment control basin during construction, there are a number of items which must be considered. The outlet structure must be modified by installation of a temporary dewatering device. Final grades are not important to establish at this time, but the minimum volume needed for sediment control must be provided for construction generated sediment.

Temporary sediment trapping device attached to a riser assembly.

Sediment removal will be needed to maintain the system's ability to reduce suspended solids. When sediment cleanout is required, the removed materials should be placed upstream of any sediment trapping facilities to prevent their movement downstream. ***The inspector will generally determine when sediment cleanout is needed and should specify where the removed sediments are to be placed.***

Very shallow grades on a constructed wetland.

B. ***The importance of accurate grade establishment in shallow constructed wetland systems cannot be overstated***. During construction, survey stakes must be placed to accurately establish cuts and fills. The final grades must be accurate for successful plant establishment and propagation. Final grades should be established prior to water filling the pond, where possible. Once the bottom and side soils have become saturated, the movement of earth material becomes much more difficult and the basin may have to be dewatered and dried before final grades can be established.

C. ***Site stabilization must be accomplished before wetland planting if site runoff passes through the facility.*** Excess sedimentation can smother the plants and change wetland elevations which would alter planting success and plant composition. Optimally, the planting should be done several months after site stabilization to allow for further reduced sedimentation into the wetland, but construction scheduling may reduce that potential.

D. The time of year that plants are placed in the wetland will influence the eventual success of the planting. Ideal times for planting are in the spring when plants are emerging from dormancy and in the late fall when plants are just entering dormancy. Other times for planting are less recommended. The inspector should discuss time frames for planting with the developer/contractor early in construction to establish a timetable for facility construction and wetland planting.

8.3. Infiltration Practices

Infiltration, or retention, practices are widely recognized as valuable stormwater management BMPs because of their multiple benefits. ***By retaining runoff onsite for percolation or evaporation, infiltration practices are the only structural stormwater BMPs which reduce the total volume of stormwater leaving an urban site.*** Infiltration practices include a wide range of BMPs including:

- trenches
- basins
- drywells
- paving (porous pavements, lattice block)
- swales

While the multiple benefits of infiltration practices make them very essential BMPs, there is a major concern, at this time, with their long term performance. Detailed evaluations of implemented infiltration facilities in Maryland (Pensyl and Clement, 1987; Lindsey, Roberts, and Page, 1991) reveal that ***infiltration systems are very sensitive to failure due to clogging of the facility's surface area***. Many instances of premature clogging of infiltration practices were attributable to poor site control during the site construction process. Poor site control results in excess sediment loadings entering the infiltration system. Therefore, quality control during construction of infiltration practices is an essential responsibility of an inspector.

Infiltration practices can include, by some definition, buffer areas, biofiltration swales, and riparian zones. However, in this chapter, infiltration swales, filtration practices, and biofiltration practices will be discussed separately. The next two sections present general information on design and construction of infiltration practices. Section 8.3.3 will present specific information for each of the individual types of infiltration BMPs.

8.3.1. Important Inspection Aspects Related to Design

Design of stormwater infiltration systems requires a greater recognition and knowledge of specific site conditions, much more so than for detention systems. Site variables play a much greater role in infiltration facility design. The site variables listed below are important to assess and evaluate if the implementation of infiltration BMPs is to be successful. From an inspector's perspective, the approved project file should contain information on each of these parameters. Specific design recommendations, based on state or local conditions, for the parameters discussed below (i.e., maximum slope, depth to water table, minimum soil permeability rates, etc.) should be provided in state or local stormwater management design handbooks.

A. Soils must be suitable for infiltrating runoff through the soil profile. Soils that have too much silt or clay content will tend to clog quicker than more coarse grained particles. ***Each infiltration facility should have a soils report attached to the approved plans which detail soil conditions at the site of the infiltration system.***

   As an initial design consideration, the appropriate Detailed Soil Survey should be consulted to determine whether a specific site is suitable for infiltration practices. If this indicates suitable soils, ***location-specific soil borings should be taken to verify soil conditions to several feet below the bottom of the infiltration facility***. The soils analysis will indicate the depth of various soils in the profile in addition to the depth of water table or bedrock. The inspector should become aware of the soils expected on the site at the proposed location of the infiltration BMP. This is to ensure, during construction, that those soil conditions are accurate.

   The Stormwater Management Manual for the Puget Sound Basin, Volume III - Runoff Control (Washington State Department of Ecology, 1986) requires runoff to pass through at least 18 inches of soil which has a minimum cation exchange capacity of 5 milliequivalents per 100 grams of dry soil. The intent of this requirement is to ensure that pollutants do not pass through soils that are too porous creating ground water pollution. The approved plans should be checked for special conditions related to construction of the infiltration system.

Example of a soil sample being taken at an infiltration basin site.

B. The design report should contain information on the depth of soil from the proposed bottom elevation of the infiltration BMP to the water table, bedrock, or impermeable soil layer. Having limited depth of good soil above a barrier to vertical water movement may prevent long term performance of infiltration practices. As these facilities accept runoff from areas of the project site that have reduced or eliminated infiltration, the accumulation and ponding of runoff in the infiltration system increases the potential for ground water mounding. ***Mounding can cause ground water levels to rise above the design bottom elevation in the vicinity of the facility. This can prevent or significantly reduce infiltration of runoff.***

   There are situations where infiltration facilities can be used despite having a high ground water table. In very permeable soils, exfiltration of runoff can occur through the sides of the facility. This process must be specifically designed for, and the plans should clearly indicate expected site conditions.

C. Site slope must be a consideration in the implementation of an infiltration BMP. Locating an infiltration system on slopes exceeding 15% could result in infiltrated

Combination detention facility and infiltration basin where exfiltration from basin occurs through the side walls.

runoff becoming surface runoff farther down the slope and increase site erosion problems. Slope can also adversely impact the performance of infiltration trenches. These are linear in nature and too steep of a slope may mean that the uphill portion of the facility never fills up with water prior to runoff overflowing the downstream end of the facility.

D. The proximity of septic fields, structure foundations, or drinking wells should be considered during the design phase to eliminate potential concerns, for obvious reasons.

E. ***Due to the sensitivity of infiltration practices to clogging, the BMP Treatment Train concept should be used to provide pretreatment***. This can be accomplished by swale conveyances, vegetative filters or structural BMPs. Pretreatment is not practical for some infiltration BMPs such as a porous pavement or dry well. However, whenever feasible, pretreatment needs to be provided. The inspector should review the plans to see if pretreatment is provided.

F. The approved plans should detail the surface covering of the infiltration system. If vegetation is the cover material, the approval should detail the seeding specification, ground preparation, and fertilizer application. Other surface covers, such as stone riprap or apron, should also be detailed. If stone is used, the stone should be clean, washed stone to reduce potential clogging of the facility.

8.3.2. Important Inspection Aspects Related to Construction

The proper construction of infiltration facilities is very important if long term performance is to be expected. These practices are very susceptible to clogging by site generated sediments. ***It is vital that sediment laden runoff during construction not be allowed to enter the facility.*** There is also a time period after site stabilization has been accomplished that excess sediment loads still are transported downstream from areas where revegetation is done. These areas of revegetation will not have the buildup of organic material or the density of vegetation that will develop eventually. This is why pretreatment of runoff before it enters the infiltration system is needed. The following general guidelines apply to the construction phase of all infiltration practices. The guidelines are adapted from those provided in the "Control of Siltation" Section of the Stormwater Management Design Manual for the Puget Sound Basin, Volume III - Runoff Control.

A. Infiltration systems should not be constructed until permanent stabilization and permanent erosion control of areas draining to the facilities has been accomplished.

B. ***Infiltration facilities, primarily basins, should not be used for temporary sediment traps or basins during construction***. If an infiltration system must be used for sediment control, the bottom of the facility should be placed at least one foot above the design bottom elevation. If the system develops a normal pool of water due to bottom clogging by finer sediments, it should be dewatered and allowed to dry before excavation to final design bottom elevations. If the material is removed while wet, there will be the potential for the water to become turbid and for finer sediments to remain in the water column. This will reduce soil permeability at the final bottom elevation.

C. Other than infiltration dry wells and porous pavement, all infiltration practices shall be designed so that the stormwater runoff first passes through a pretreatment system to remove suspended solids before the runoff enters the infiltration system.

D. ***The location of infiltration systems should be clearly marked at the site to prevent vehicle traffic across this area***. The traffic will compact the soils and reduce soil infiltration rates. As can be seen from the photograph, identification without education may not prevent a problem from occurring.

While the location of the infiltration basin was marked, construction workers mistakenly thought the markings identified where trucks were to enter and leave a construction site.

8.3.3. Characteristics of Individual Infiltration Practices Which Warrant Specific Attention

Although grouped together due to their common goals, infiltration BMPs also are very different in their construction and site utilization. Consequently, they will be discussed separately to provide specific guidance to the inspector. Probably the best existing source of information on construction inspection of infiltration systems is the "Inspectors Guidelines Manual for Stormwater Management Infiltration Practices" (Maryland Department of the Environment, 1985). Many of the recommendations in the following section have been adapted from it. These recommendations need to be considered in addition to those presented in the general discussion in Section 8.3.2 above. In addition, detailed construction check sheets are provided in Appendex 6-5.

A. ***Infiltration basins*** often do not have a principal spillway since runoff is infiltrated into the ground or evaporated. The primary method of construction is to construct a dam embankment or to excavate a basin into the ground. These facilities temporarily store (underlined for emphasis) runoff. They are generally used for larger drainage areas than are other types of infiltration BMPs. There are a number of points (See Appendix 6-5A) which must be considered by an inspector when inspecting an infiltration basin.

1. The infiltration basin dimensions and locations should be verified onsite prior to basin construction. Design considerations such as distance to foundations, septic systems, wells, etc. need to be verified.

2. Initial excavation should leave more than one foot of unexcavated material above the design bottom eleva-

tion if the basin is to be used for sediment control during construction. However, ***it is recommended that infiltration basins not be used for erosion and sediment control during construction***.

Example of an infiltration basin being constructed.

3. ***During initial excavation, the excavated materials should be observed by the inspector to verify soil conditions are consistent with information in the design report***. Significant variation of soils from the design report should be noted and the plan approval agency notified.

4. Excavation should be done by lightweight equipment to minimize the potential of soil compaction. Tracked, cleated equipment does less soil compaction than tired equipment.

5. When inspecting the basin floor at final grade establishment, the inspector should look for any material, organic or otherwise, which may reduce basin performance. Examples of such material includes tree roots, previously buried material, or areas of loose stone.

6. Where embankments are required for basin establishment, the same concerns that exist for detention ponds should be considered. This includes:

   - clear, grub, and strip topsoil
   - a cutoff trench
   - fill material for the embankment shall be taken from an approved source and be clean mineral soil free of roots or woody vegetation.
   - embankment compaction shall be the same as for detention ponds in terms of degree of compaction and depth of layers

7. ***When at final grade, the basin floor should be deeply tilled to restore the percolation rate of compacted soils and to aerate the soils***.

8. Similar to detention systems, infiltration basins should have a final inspection performed leading to preparation of written documentation on the adequacy of construction.

B. Infiltration Trenches tend to have a large length to width ratio and are filled with stone, gravel, or sand aggregate. Infiltration trenches are generally used in areas where space available for the BMP is limited. By being linear, and having the available area filled with stone, etc. they can be fairly deep without having a comparable width requirement. Runoff entering the facility is stored in the void areas of the aggregate material, which normally is between 30 and 40% void area. The stored runoff then exits the trench through the side and bottom walls into the soil profile. Appendix 6-5B contains an inspector check list for infiltration trenches.

Completed infiltration basin; note the lack of pretreatment measures prior to runoff entry into the facility.

1. The infiltration trench dimensions and location should be verified onsite prior to trench construction. Design considerations such as distance to foundations, septic systems, wells, etc. need to be verified.

2. The trench should be excavated using a backhoe or a ladder type trencher. Front-end loaders or bulldozers should not be used as their blades can seal the infiltration soil surface. Excavated materials should be placed a sufficient distance from the sides of the excavated area to minimize the risk of sidewall cave-ins and also to prevent migration of the soils back into the trench after the stone, gravel, or sand aggregate has been placed.

3. The trench bottom and side walls should be inspected for removal of objectionable material such as tree roots that protrude and could possibly puncture or tear the filter fabric.

4. The sides and bottom should be lined with filter fabric. The side fabric placement will prevent migration of soil particles from the side walls into the trench. The bottom filter fabric will prevent sealing of the aggregate soil interface.

5. The fabric should be laid with sufficient length to overlap the top of the trench. Having the trench covered after placement of the aggregate will protect the completed facility by preventing excess site sediment from entering it.

6. An observation well should be installed in the aggregate to allow future inspections to determine whether the facility is functioning as designed. The observation well should consist of a perforated PVC pipe, 4 to 8 inches in diameter and have a foot plate and a cap. The footplate will prevent the entire observation well from lifting up when the cap is removed during future inspections.

Infiltration trench showing the observation well, foot plate, and filter fabric side walls before placement of the aggregate.

Example of an infiltration trench treating highway runoff.

7. The aggregate material should be inspected prior to placement to ensure that it is clean material and free of debris. The size of the material should be as specified on the approved plans.

8. Upon completion of trench construction, the adjacent areas should be vegetatively stabilized. The overflow of the trench should be directed to a non-erosive outlet channel.

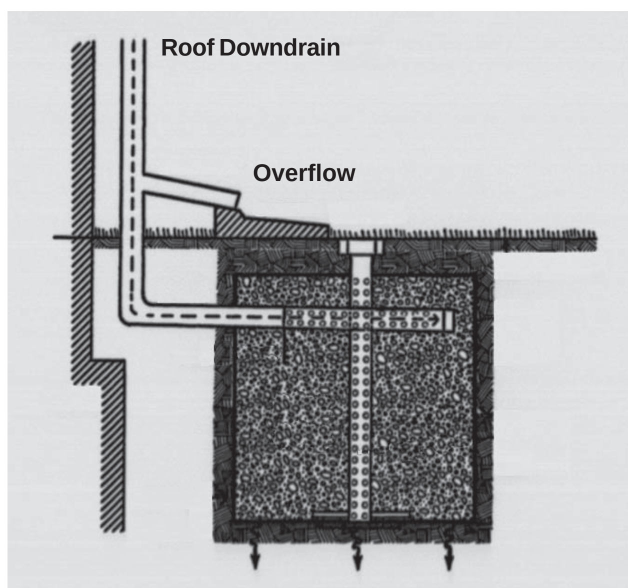
9. A pretreatment BMP should be used before the runoff enters the trench. This pretreatment should be effective at removing suspended solids and can be a biofiltration swale or other approved method.

10. The observation well should be capped and the initial depth measured and noted on the inspection checklist.

C. *Infiltration Drywells* are similar to infiltration trenches in that they are excavated areas that are filled with an aggregate material. The main difference is that drywells accept runoff from roofs. Therefore, they receive lower loadings of suspended solids loadings compared to that expected from ground surface runoff. The major concern with infiltration drywells is that, by serving roof areas, they must be located in the vicinity of building foundations. ***Careful consideration must be given to the correct placement of drywells so that building foundation problems do not result.*** A big advantage of a drywell over other runoff controls is that the drywell is underground and does not represent a loss of site area to the land developer. Appendix 6-5C contains an inspector check list for drywells.

1. The infiltration drywell dimensions and location should be verified onsite prior to drywell construction. Design considerations such as distance to foundations, septic systems, wells, etc. need to be verified.

2. The drywell should be excavated using a backhoe or ladder type trencher. Front-end loaders or bulldoz-



Schematic of an infiltration dry well.
Adapted from Schueler, 1987

ers should not be used as the equipment blades may cause excessive compaction of the drywell bottom.

3. Excavated materials should be placed a sufficient distance from the sides of the excavated area to minimize the risk of sidewall cave-ins and also to prevent migration of the soils back into the trench after the stone, gravel, or sand aggregate has been placed.

4. The drywell bottom and side walls should be inspected for removal of objectionable material such as tree roots that protrude and could possibly puncture or tear the filter fabric. Work should be scheduled so that the drywell can be covered in one day to prevent windblown or water carried suspended solids from entering the drywell.

5. The sides and bottom should be lined with filter fabric. The side fabric placement will prevent migration of soil particles from the side walls into the trench. The bottom filter fabric will prevent sealing of the aggregate soil interface.

6. Once the aggregated has been placed, filter fabric should be placed over the drywell and final grading should be done.

7. An observation well should be installed in the aggregate to allow future inspections to determine whether the facility is functioning as designed. The observation well should consist of a perforated PVC pipe, 4 to 8 inches in diameter and have a foot plate and a cap. The footplate will prevent the entire observation well from lifting up when the cap is removed during future inspections.

Completed drywell showing overflow device: note total site utilization but also the lack of observation wells.

8. The aggregate material should be inspected prior to placement to ensure that it is clean material and free of debris. The size of the material should be as specified on the approved plans.

9. Debris and grit traps consisting of fine-mesh screen covering the downspout (roof leader) should be used with dry wells to prevent objectionable materials from entering the aggregate subbase through the inflow pipe. Roof gutter screens should also be used to protect gutters and grit traps from clogging due to washoff of leaves, pine needles, etc. from

the roof area.

10. The observation well should be capped and the initial depth measured and noted on the inspection checklist.

D. ***Infiltration paving (porous pavement and lattice block) systems*** are road and parking lot surfaces whose design allows for stormwater runoff to travel through the surface into the ground. Under the porous surface, an aggregate material serves as a reservoir base for temporary storage of the runoff until the water infiltrates into the ground. ***Their best applications are in areas where there is a low volume of traffic or where overflow parking is needed on a periodic basis.*** Appendix 6-5D contains an inspection check list for pervious pavements.

Porous Asphalt

This has been the most commonly used porous paving surface. In porous asphalt the fines are left out of the mix and the asphalt content is increased slightly to increase the binding of the mixture. Leaving the fines out of the mixture increases the void spaces and allows rainfall to pass directly through the pavement. The paving consists of the porous asphalt course, a filter course, the reservoir course, filter fabric, and finally the existing soil.

Porous paving being installed showing the porous asphalt course and the filter course.

Lattice Block

Lattice block is a modular unit which is generally placed in square sections. It is concrete with large void areas which are filled with a porous material, such as sand or pea gravel. Lattice block still should have the filter course, reservoir course, and filter fabric lining, prior to entry into the soil.

Lattice block infiltration provided at a parking lot.

Pervious Concrete

Pervious portland concrete is being used widely in Florida to create porous parking areas. Like porous asphalt, the fines are left out of pervious concrete creating an open concrete pavement which allows water to pass directly through into the ground. It avoids some of the pitfalls of porous asphalt due to its strength to resist rutting and compaction. It also has greater surface openings to resist surface clogging which is such a large concern with porous paving. ***However, special expertise is required to batch, pour, and finish pervious concrete***.

1. To help preserve the natural infiltration rate of the subgrade soils prior to excavation, the infiltration paving area should not be excessively traveled by heavy construction equipment that causes excessive compaction of soil pores. The area should be marked off and traffic kept off it to the greatest extent possible.

2. The infiltration paving dimensions and location should be verified on-site prior to construction. Design considerations such as distance to foundations, septic systems, wells, etc. need to be verified.

3. The area of the paving should be carefully excavated to prevent excessive compaction of the soils during the subgrade preparation. All grading should be carried out using wide tracked equipment.

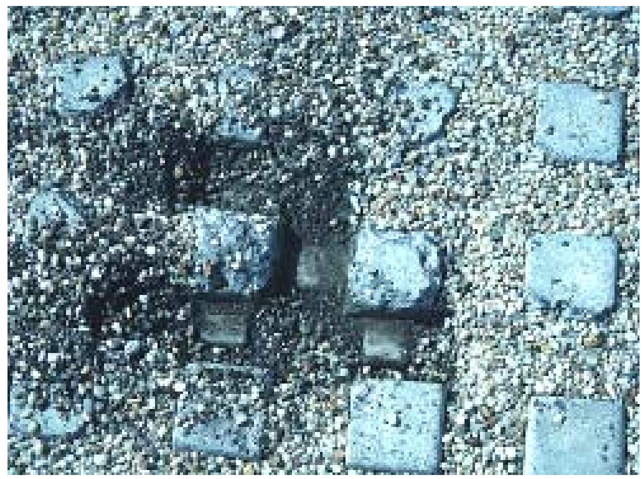
4. Once the subgrade has been reached, filter fabric should be placed on the bottom. The type of fabric should be specified on the approved plans.

5. Once the fabric has been placed, the reservoir course is placed to the design depth. This course should be clean, washed stone having a void ratio between 30 and 40%. The reservoir course should be laid in 12" lifts and lightly compacted. The aggregate should be uniformly spread.

Placement of the reservoir base at a porous pavement site.

6. The aggregate filter is placed on the reservoir course and is clean washed stone ranging in size from 3/8 to 5/8 inch. This stone provides a uniform base for the asphalt or lattice course.

7. At no time should sediments be allowed to enter the infiltration paving construction area.



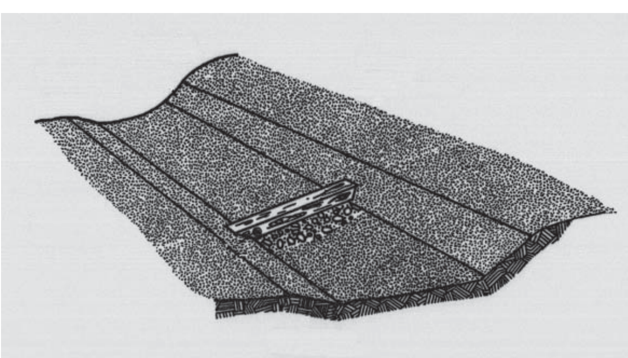
Close-up view of lattice block paving with pea gravel filler in the porous areas.

8. The surface course is then laid. If porous asphalt, it should be laid directly over the aggregate filter course in one lift. The laying temperature should be done to local specifications and minimum air temperatures should be considered to ensure that cooling does not occur prior to compaction. If lattice block is used, temperature of the mix or air temperature aren't important. The void areas of the lattice block should be filled with the appropriately specified material.

9. The inspector should check the overall workmanship of the pavement area to ensure smooth transitions between existing and new paving. A small compacted section should be tested by pouring a few gallons of water onto the pavement to ensure that the water infiltrates into the pavement.

E. *Infiltration Swales* are closely related to biofiltration swales. The primary difference is these swales use infiltration as their primary means of pollutant and total runoff volume reduction. However, they are still considered as a subset of biofilters since vegetative filtration is also important. While biofiltration swales and filters rely on passage of water through vegetation for pollutant reduction, infiltration swales have designed blockages, such as swale blocks or check dams, which pond water and promotes infiltration. In both situations, slopes must be very gradual to increase residence time and reduce flow velocities. Appendix 6-5E contains an inspection check list for infiltration swales.

1. To help preserve the natural infiltration rate of the subgrade soils prior to excavation, the infiltration swale area should not be excessively traveled by heavy construction equipment that causes excessive compaction of soil pores. The area should be marked off and traffic kept off the area to the greatest extent possible. This is especially important at residential construction sites where individual residential contractors enter building sites with numerous trucks. The driveway areas should be the access points for contractors.



Schematic of an infiltration swale.
Adapted from Schueler, 1987

2. The infiltration swale dimensions and location should be verified onsite prior to construction. Design considerations such as distance to foundations, septic systems, wells, etc. need to be verified.

3. Excavated materials should be placed a sufficient distance from the sides of the excavated area to prevent migration of the soils back into the swale area.

4. During excavation of the swale cross-section, poor soils, organic material, or rocks should be removed and replaced with permeable soils.

5. Excavation should be done by lightweight equipment to minimize compaction of the soil profile.

6. The approved design plan will have specifications for the composition of the swale block or check dam (height, slopes, materials, etc.). They will generally be earth material and should be compacted to minimize seepage. Stone or sod may be required on the face of the check dam to prevent possible erosion during high storm flows.

7. The final inspection will verify infiltration swale dimensions, and assure that the number of check dams

agrees with the approved plans. ***It is absolutely essential that excess sediment loadings be kept out of the swale and that good vegetative stabilization of the swale be accomplished***. Infiltration swales, due to their small impounded areas behind the check dams, are very susceptible to clogging of the pool areas, so good stabilization of the site and swales is essential.

Infiltration swale adjacent to a highway.

8.4 Filtration Systems

Filtration systems are becoming more recognized and accepted as another option for treatment of urban stormwater. There are three primary approaches which are being used around the country. These approaches require very different responsibilities for an inspector.

<u>Austin, Texas</u>

The City of Austin has pioneered the use of sand filter systems as a means to protect their ground water aquifers. Austin has significant limestone areas in which discharge of stormwater could increase the potential for sinkhole development and allow pollution of ground water resources by direct discharge of untreated stormwater into the ground water. They use impermeable lin-

Austin sand filter system sediment forebays on either side with sand filter in the center.

ers under their sand filters to prevent the potential migration of pollutants into the ground water while treating the runoff. The program requires management of both stormwater quantity and quality, with treatment of runoff from pervious and impervious areas.

<u>Washington D.C.</u>

The City of Washington, D.C. is on a combined sewer system. Their sand filter systems also are designed to control the peak rate of discharge from a site while providing stormwater treatment. The stormwater quantity criteria are intended to prevent overloading the combined sewer capacity. The basic sand filter design used is an underground vault since land is either very expensive or unavailable for use of surface stormwater BMPs.

Washington, D.C. sand filter.

Delaware Sand Filter

Delaware's stormwater program has developed a sand filter design for use on highly urbanized sites where available stormwater treatment options are limited. This filter is designed for water quality only, and is used to treat runoff from totally impervious drainage areas at smaller sites. The filter is a shallow system which can be built underground resulting in no loss of site use for buildings.

Delaware sand filter.

There are other variations to these three basic designs. The City of Alexandria uses variations of all three approaches. Their variation of the Delaware Sand Filter uses a precast concrete top for the filter which significantly reduces the cost compared to the original Delaware version where cast iron grates are commonly used. Florida's stormwater program pioneered the use of detention with filtration systems in the early 1980s. Side bank and vertical recovery filters, made of sand and gravel, are used in association with detention systems to provide stormwater treatment on sites that can not use wet detention.

8.4.1. Important Inspection Aspects Related to Design

Design of filter systems is fairly straightforward when compared with ponds or other practices. Their design criteria are clearly detailed in available guidance manuals. One similarity of all of the different confined filters is a two chamber facility. The first chamber is for sediment deposition of larger suspended solids. The second, a filtration chamber, contains the filter media, generally sand. Other filter media including compost, peat, and alum sludge have been used on specific projects. Appendix 6-6 is an inspector check list for filtration systems. In addition, the plans should include the following information:

A. Dimensions and structural details of the filtration facility.

B. Sequence of construction for overall site development and construction of the filtration facility.

C. Volumes and size of both the sedimentation and filtration chambers.

D. Specifications of the filter media. The media should be specified as being clean, washed material.

City of Austin sand filter for new highway construction. The chamber in the foreground is the sedimentation chamber, the filtration chamber is in the background.

E. Sediment control provisions during construction to prevent the facility from premature clogging. The Austin filters include a dry detention component. Accordingly, these facilities may have more construction sediment control notes than the other systems.

F. In the Delaware sand filter, the filter may be prefabricated in standardized lengths. The means of sealing the joint connections between units should be specified on the approved plans.

City of Alexandria variation of the Delaware sand filter using prefabricated concrete tops for the filter.

8.4.2. Important Inspection Aspects Related to Construction

As can be seen from the illustrations, sand filters may involve reinforcing steel, concrete, and significant site preparation prior to construction. The inspector should carefully review the approved plans and discuss any concerns at the preconstruction meeting. From an inspection standpoint the following construction times and items are important to recognize during the site inspection.

A. Site location for the filtration facility should be staked out. This is especially important when installing the Austin filter as it encompasses more site area than do the Washington D.C. or Delaware filters. In general, filters should not be used for sediment control during construction.

B. Structural components should be available on-site to verify adequacy of materials. Reinforcing bars should meet specifications as should all other structural components such as any pipes, aggregate material, and filter fabric.

C. Foundation areas should be cleared of any organic material which could cause uneven settlement at the material decomposes. Unsuitable foundation material should be removed and replaced by suitable material.

D. The foundation area should be compacted to sustain the load placed on it by the filtration system. The foundation should then be leveled as detailed on the plans to ensure proper drainage of the facility.

E. The inspector should be on site when the facility has been formed up with reinforcing bars in place but prior to pouring of the concrete.

Foundation grade being established prior to placement of concrete floor of the filtration facility.

F. During concrete pouring, the inspector shall verify that the concrete meets design specifications for the design load.

G. If the filtration facility is composed of prefabricated units, the inspector shall approve the means of joining the sections and the steps taken to prevent leakage from between the prefabricated units.

Sealing of joints on a prefabricated delaware sand filter.

H. Delaware and Washington D.C. filters should be filled with water once the concrete has set (or joints sealed on prefabricated units) and allowed to sit for 24 hours to observe whether the unit has any leaks.

I. When installation has been completed, meets size and volume requirements, has no leakage, and the contributing drainage areas have been stabilized, placement of the underdrains should then be done. These drains should be placed on the proper slope and wrapped in filter fabric to prevent migration of the filtration material out of the facility.

J. The filter material shall then be placed in the facility. The material should meet criteria specified on the design plans. A common material used at this time is C-33 concrete sand. This is clearly defined in highway design standards. The sand should be clean, washed aggregate. Other materials, such as peat or compost, may become more accepted if their performance demonstrates their value.

K. A final inspection should verify that the filter material is placed correctly and the first sedimentation chamber is clean of any accumulated sediments or other construction debris.

8.5. Biofiltration Systems

Biofiltration practices rely upon several processes to treat runoff. These include filtration, infiltration, adsorption, and the biological uptake of pollutants from runoff as it flows through a vegetated stormwater treatment system. Biofiltration can effectively function in any location where natural vegetation and landscaping intercept runoff. ***A key requirement of any vegetative treatment system is to obtain a stand of vegetation that can effectively filter runoff.*** Ideal vegetation characteristics include a dense, uniform growth of fine-stemmed plants that can tolerate soil saturation and the climatological, soil, and pest conditions of the area. Drainage areas are generally fairly small, less than 5 to 7 acres. Appendix 6-7 is an inspector check list for biofiltration practices.

It is essential to maintain proper hydraulic conditions to avoid uneven, channelized flows through the biofiltration BMP. Uneven flow across the width of a biofilter reduces pollutant removal effectiveness because runoff bypasses vegetation, shortening treatment time. Channelized flow also may erode biofilters and exacerbate downstream water quality prob-

Vegetative swale functioning as a biofiltration facility.

lems that the BMP was intended to mitigate.

8.5.1. Important Inspection Aspects Related to Design

Design of biofiltration facilities is fairly straight forward. Their primary treatment process is filtering runoff through vegetation. When an inspector first reviews the approved plans, it is important to note the following essential design aspects of biofiltration BMPs.

A. Dimensions and structural details of the biofiltration system. The bottom width of swales should be no less than 2 feet if it is to be mowed. The bottom width should be no greater than 8 feet unless it will be hand finished to get a completely level bottom.

B. Sequence of construction for overall site development and construction of the biofiltration system.

C. Do the post-development drainage patterns resemble the pre-development ones? Placement of swales and biofilters along natural flow paths and contours should be detailed on the approved plans.

D. To assure even sheet flow in a biofilter, and avoid channelized flow, ***the bottom of the biofiltration BMP must be flat with no lateral slope*** (across the bottom of the swale or vegetative filter strip).

E. ***The design of inflow to the biofilter should quickly dissipate runoff velocity to minimize erosion potential.*** Dissipation practices such as riprap pads and level spreaders should be used.

Swale inlet energy dissipator and flow spreader.

F. Outflow from biofilters should be diffuse to avoid erosion damage to downstream facilities or water bodies. Swales should be equipped with raised storm drain outlets to prevent erosion.

G. Generally, biofiltration swales are longer than 100 feet to reduce short circuiting, with their total length depending upon the flow and the minimum required residence time. No minimum width has been established for biofiltration filter strips since this is a very site specific design parameter. All of the above distances are general recommendations to provide effective stormwater treatment. Exact dimensions and residence times will be specified by the state or local stormwater program depending on their performance standard. These dimensions must be specified on the approved plans. When an inspector finds that a biofiltration system is not built according to the design plans, the plan approval agency should be contacted to determine corrections needed to ensure proper performance of the constructed BMP.

H. Longitudinal slopes should be fairly slight with maximum slopes of 4% (can be greater with use of check dams).

Check dam with energy dissipator.

I. Plant specifications must be contained on the approved plans. ***Grasses tend to be the superior choice of vegetation as they are resilient, provide abundant surface area, and can sprout through thin deposits of sand and sediments***. The plants should be those of common use in the geographic area and be somewhat stiff, dense, and a greater leaf area.

J. If the site's soils are sandy, topsoil should be specified on the biofilter's plans. Eliminating hardpan, rocks, and gravel near the surface will help to prevent persistent bare spots in biofilter plant cover.

K. Pretreatment should be provided when high sediment inputs to biofilters are likely.

8.5.2. Important Inspection Aspects Related to Construction

Construction activities should be phased to ensure the greatest practical amount of plant cover during the course of construction. If permanent swales and filter strips are installed during site construction, they either must be protected from construction site runoff or restored for long term use once site construction is completed. The inspector should note the following important aspects of construction:

A. Site location for the biofiltration facility should be staked out. This will allow for dimensions, shapes, and slopes to be verified per the design plans.

B. ***Ensure that lateral slopes are completely level to avoid any tendency for the flow to channelize***.

C. Ensure that inlets, outlets, and other auxiliary structures, such as check dams or flow bypasses, are installed as specified.

D. ***Make sure that vegetation complies with planting specifications***. Ensure that vegetation becomes uniformly dense for good filtration and to prevent erosion. Grass can be established by seeding or using sod. Seeding is generally preferred due to it's lower cost and the greater flexibility it allows in selecting grass species. ***The method of vegetative stabilization should be discussed and approved at the preconstruction meeting***.

E. ***The biofilter should be placed so that no portion will be in the shade of buildings or trees throughout the entire day***, which would cause poor plant growth.

F. Make sure that construction runoff is not entering the biofilter. If it is, require re-

Swale biofilter having erosion control matting installed prior to permanent vegetative stabilization.

moval of sediments and reestablish vegetation upon the completion of construction.

G. Ensure that measures are in place to divert runoff while vegetation is being established. If runoff is probable and cannot be diverted, ensure that adequate erosion control measures are in place.

H. Inspect liners, underdrains, riprap, and check dam spacing, if they are included in the approved plan.

I. Make sure that any level spreaders are completely level and sufficiently stable to remain level during their operation.

The same biofiltration swale with permanent vegetative stabilization three weeks later.

J. Check for proper installation of pretreatment devices, if required.

K. Ensure that curb cuts and their locations are as specified. ***Ensure that the vegetation is not higher than the curb cut*.**

9. ONCE CONSTRUCTION IS COMPLETED

Upon satisfactory completion of construction, there are several actions that should be taken with respect to the completed project and its files. The information can be entered in any many ways. It can include microfilming the plans, having a data spreadsheet for pertinent information, or maintaining a physical file of the completed project containing all information needed for future inspections and actions. ***It is very important that this process includes a means of notifying the inspection agency to make them aware of the need for future inspections.***

This process starts upon completion of the construction phase of the project. Specific tasks include:

- Entering pertinent information from the completed files into a database. Future retrievals of this information will provide the basis for future maintenance inspections.
- The "As-Builts" or Record Drawings should be attached to the file and made an essential part of the permanent record. It is becoming more common for electronic cad (autocad) drawings to be required, allowing communities a more efficient means of updating system-wide stormwater inventory maps.
- Copies of all inspection reports and the final inspection report should be placed in the file.

- The permanent file should tell who is responsible for subsequent maintenance inspections and physical maintenance of the completed facility. These responsibilities should be set forth in a legal document, signed by the individual assuming maintenance responsibility. This will help to assure their commitment to assuming and performing these tasks.

- The date for a subsequent maintenance inspection should be established at this time to ensure the initiation of permanent ongoing inspections of the completed facility.

10. RECOMMENDATION FOR INSPECTOR TRAINING AND CERTIFICATION PROGRAMS

Initial and subsequent on-going training are essential for inspectors to learn the initial skills and maintain their level of understanding. It is also important that they be aware of their obligations on new types of BMPs or variations in design of existing BMPs.

Inspector training should include a specific course designed to provide inspectors with the minimum information necessary to conduct site inspections during and after construction. This course should be given to public inspectors and private individuals who are responsible for inspecting and maintaining stormwater management systems. This training is a mandatory program component if the program's law or rules require inspections during or after stormwater system construction. The educational program should include, at a minimum, the following items.

- Why implementation of stormwater management facilities is important.
- Applicable laws and regulations.
- What the individual types of facilities are and how they function in various scenarios.
- How to read a design plan and accompanying specifications.
- How to inspect a site.
- How to complete an inspection form.
- How to read a topographic map.
- Soils information including knowledge of soil texture, consistency, etc. to be able to recognize various soils in the field.
- Site erosion and sediment control strategies and practices for consideration in protection of stormwater management facilities.
- Enforcement procedures and penalty provisions.
- Detailed information on local vegetation including information on suitability of various types of vegetation for different purposes. This would include vegetation that is water and drought tolerant.

Education is essential to effective program implementation. Education on stormwater system construction is an important component of this overall educational process. ***Without education, the expectations for successful construction of stormwater management systems is reduced.*** The training recommended in this chapter could be supplemented with the educational program discussed in Chapter 7. The training probably is best done by including it in an educational program on site construction which should include erosion and sediment control and stormwater management system construction. The issue of how many educational programs and the extent of each program is best made at the local level where the programs are most appropriately given.

APPENDICES

Construction Inspection Forms
for
Stormwater Management
Facilities

APPENDIX 6-1

Preconstruction Inspection Meeting Topics Form

State of New Jersey
Department of Environmental Protection
Stormwater Management Facility Maintenance Manual

Example Preconstruction Meeting Topics

A. GENERAL INFORMATION

1. Attendance
2. Purpose of project and background information
3. Emergency telephone numbers
4. Construction photograph requirements
5. Project sign requirements
6. Starting date
7. Review of contract documents, including insurance certifications, bonds and subcontractors documents
8. Field office requirements
9. Responsibility for notification of affected property owners and residents
10. Chain of command for communications and correspondence
11. Construction schedules
12. Key personnel and their degree of involvement in the project (inspector, owner, engineer, agencies, etc.)

B. POLICE AND FIRE DEPARTMENT CONCERNS

1. Traffic control
2. Barricades and signs conforming to the uniform manual
3. Noise ordinance considerations
4. Working hours, including weekend and holidays
5. Vandalism and preventative measures
6. Flagmen and traffic control officers
7. Equipment storage and vehicle parking
8. Emergency vehicle access
9. Underground tank locations and precautionary construction procedures
10. Storage and use of hazardous materials

C. UTILITIES

1. Utility locations and mark-outs
2. Coordination of utility relocations
3. Emergency phone numbers of utility companies

D. FUNDING AND PAYMENTS

1. Funding sources and availability
2. Procedures and dates for payment estimates
3. Dates for payments to contractor
4. Breakdown of lump sum items for partial payment
5. Policy for payment for materials on site at the close of a payment period

6. Retained monies during and after construction
7. Requirements of funding agencies

E. CHANGE ORDERS AND EXTRA CLAIMS

1. Requirements for additional work and submittal of change orders
2. Procedures and schedule for review and recommendations of change orders
3. Procedures for negotiating extra claims and change orders

F. CONSTRUCTION ACCESS AND EASEMENTS

1. Easement locations and maps
2. Responsibility for locating and staking easements
3. Available survey data for the site
4. Access requirements and staging areas
5. Easement restrictions and restoration requirements

G. CONSTRUCTION DETAILS

1. Unique or complex aspects of the project
2. Testing laboratories and sampling procedures
3. Cold and hot weather protection measures
4. Blasting requirements
5. Dump site location for construction related materials
6. Shop drawing requirements and review procedures
7. Specific construction techniques and procedures
8. Review of technical section of the specifications

H. PERMITS

1. Status of all required federal, state, and local permits
2. Permit restrictions and conditions
3. Start-of-work notifications

APPENDIX 6-2

General Site Inspection and Notice to Comply Forms

Construction Inspection Report Form

(adapted from State of Delaware Sediment and Stormwater Program)

Date ________________ Time ____________________

Project ____

Location ____________________________________

Individual Contacted ___________________________

Weather Conditions ____________________________

Site Status _________________ (active, inactive, completed)

Site Conditions:

acceptable _______
Unacceptable _______
In compliance with approved plan ________
Approved plan is adequate for the site ________

Written Comments:

____
____
____
____
____
____
____

Action to be taken:

No action necessary. Continue routine inspections __________
Correct noted site deficiencies by _____________________
1st notice ________
2nd notice _______
Submit plan modifications as noted in written comments by ______________________
Notice to Comply issued __________
Final inspection, project completed __________
Other ____

________________________ ________________________
Received by Inspector

I acknowledge receipt of this inspection report. My signature does not imply agreement or disagreement with its content.

Questions or comments regarding this inspection report should be directed to the appropriate inspection agency at the appropriate address and phone number report.

white: developer/contractor yellow: file pink: legal/enforcement

Notice to Comply Inspection Report Form

(adapted from State of Delaware Sediment and Stormwater Program)

Date ____________

To: ____

Address: ____

____

Project/Site/Contract Name ____

An inspection of the above referenced project on _________________________(Date) revealed that the site is not in compliance with the approved Sediment Control and Stormwater Management Plan, approved Plan amendments, Law, or Regulations, and the following violations exist:

____

____

____

____

____

____

____

____

____

____

Notice is hereby given that the above violations shall be corrected in accordance with the approved Sediment Control and Stormwater Management Plan, approved Plan amendments, Law, or Regulations on or before _____________________________ (Date). The site will be re-inspected at that time to determine if the site has been brought into compliance with the approved Plan, approved Plan amendments, Law, or Regulations.

Failure to comply with this notice will result in the initiation of legal action by the Department in order to bring the site into compliance with the approved Plan, approved Plan amendments, Law, or Regulations.

_____________________________   _____________________________

Received by   Inspector

I hereby acknowledge receipt of this notice to comply. My signature does not imply agreement or disagreement with its content.

Questions or comments regarding this inspection report should be directed to the appropriate inspection agency at the appropriate address and phone number

white: developer/contractor   yellow: file   pink: legal/enforcement

APPENDIX 6-3

Sediment/Stormwater Management Basin Construction Inspection Checklist

Sediment/Stormwater Management Basin Construction Checklist

For Permanent structures per Delaware NRCS Pond Code 378 and Delaware Sediment and Stormwater Regulations
(Developed by Randy Greer, Environmental Engineer)

KEY	***PROJECT INFORMATION***
__▯__ Item meets standard	Project ID: ____________________
__▯__ Item not acceptable	Contractor: ____________________
N/A Item not applicable	Inspector: ____________________
C Item requires engineer's certification	Date(s): ____________________

I. Materials and Equipment

______ Pipe and appurtenances on-site prior to construction and dimensions checked.
- ______ 1. Material (including protective coating, if specified)
- ______ 2. Diameter
- ______ 3. Dimensions of metal riser or pre-cast concrete outlet structure
- ______ 4. Required dimensions between water control structures (orifices, weirs, etc.) are in accordance with approved plans
- ______ 5. Barrel stub for prefabricated pipe structures at proper angle for design barrel slope
- ______ 6. Number and dimensions of prefabricated anti-seep collars
- ______ 7. Watertight connectors and gaskets
- ______ 8. Outlet drain valve

______ Appropriate compaction equipment available, including hand and small power tamps
______ Project benchmark near pond site
______ Equipment for temporary de-watering

II. Subgrade Preparation

______ Area beneath embankment stripped of all vegetation, topsoil, and organic matter
______ Cut-off trench excavated a minimum of 4 feet below subgrade and minimum 4 feet below proposed pipe invert, with side slopes no steeper than 1:1
______ Impervious material used to backfill cut-off trench

III. Pipe Spillway Installation

______ Method of installation detailed on plans

A. Bed preparation
- ______ Installation trench excavated with 1:1 side slopes
- ______ Stable, uniform, dry subgrade of relatively impervious material *(If subgrade is wet, contractor shall have defined steps before proceeding with installation)*
- ______ Invert at proper elevation and grade

B. Pipe placement

_____ Metal/Plastic pipe

_____ 1. Watertight connectors and gaskets properly installed

_____ 2. Anti-seep collars properly spaced and having watertight connections to pipe

_____ 3. Backfill placed and tamped by hand under "haunches" of pipe

_____ 4. Remaining backfill placed in max. 8" lifts using small power tamping equipment until 2 feet cover over pipe is reached

_____ Concrete pipe

_____ 1. Pipe set on blocks or concrete slab for pouring of low cradle

_____ 2. Pipe installed with rubber gasket joints with no spalling in gasket interface area

_____ 3. Excavation for lower half of anti-seep collar(s) with reinforcing steel set

_____ 4. Entire area where anti-seep collar(s) will come in contact with pipe coated with mastic or other approved waterproof sealant

_____ 5. Low cradle and bottom half of anti-seep collar installed as monolithic pour and of an approved mix

_____ 6. Upper half of anti-seep collar(s) formed with reinforcing steel set

_____ 7. Concrete for collar of an approved mix and vibrated into place. (Protected from freezing while curing, if necessary)

_____ 8. Forms stripped and collar inspected for honeycomb prior to backfilling. Parge if necessary

C. Backfilling

_____ Fill placed in maximum 8" lifts

_____ Backfill taken minimum 2 feet above top of anti-seep collar elevation before traversing with heavy equipment

IV. Riser/Outlet Structure Installation

A. Metal riser

_____ Riser base excavated or formed on stable subgrade to design dimensions

_____ Embedded section of aluminum or aluminized pipe to be painted with zinc chromate or equivalent on **inside and outside** surfaces

_____ Set on blocks to design elevations and plumbed

_____ Reinforcing bars placed at right angles and projecting into sides of riser

_____ Concrete poured so as to fill inside of riser to invert of barrel

B. Pre-cast concrete structure

_____ Dry and stable subgrade

_____ Riser base set to design elevation

_____ If more than one section, no spalling in gasket interface area; gasket or approved caulking material placed securely

_____ Watertight and structurally sound collar or gasket joint where structure connects to pipe spillway

C. Poured concrete structure

_____ Footing excavated or formed on stable subgrade, to design dimensions with reinforcing steel set

_____ Structure formed to design dimensions, with reinforcing steel set as per plan

_____ Concrete of an approved mix and vibrated into place. (Protected from freezing while curing, if necessary)

_____ Forms stripped and structure inspected for "honeycomb" prior to backfilling. Parge if necessary

V. Embankment Construction

A. Fill material
_____ Soil engineer's test
_____ Visual test by inspector

B. Compaction
_____ Soil engineer's test
_____ Visual test by inspector

C. Embankment
_____ Fill placed in maximum 8" lifts and compacted with appropriate equipment
_____ Constructed to design cross-section, side slopes and top width
_____ Constructed to design elevation plus allowance for settlement

VI. Impounded Area Construction

_____ Excavated/graded to design contours and side slopes
_____ Inlet pipes have adequate outfall protection
_____ Forebay(s)
_____ Wet pond requirements
_____ 1. 10 feet reverse slope bench one foot above normal pool elevation
_____ 2. 10 feet wide level bench one foot below normal pool elevation

VII. Earth Emergency Spillway Construction

_____ Spillway located in cut or structurally stabilized with riprap, gabions, concrete, etc.
_____ Excavated to proper cross-section, side slopes and bottom width
_____ Entrance channel, crest, and exit channel constructed to design grades and elevations

VIII. Outlet Protection

A. End section
_____ Securely in place and properly backfilled

B. Endwall
_____ Footing excavated or formed on stable subgrade, to design dimensions and reinforcing steel set, if specified
_____ Endwall formed to design dimensions with reinforcing steel set as per plan
_____ Concrete of an approved mix and vibrated into place. (Protected from freezing, if necessary
_____ Forms stripped and structure inspected for "honeycomb" prior to backfilling. Parge if necessary

C. Riprap apron/channel
_____ Apron/channel excavated to design cross-section with proper transition to existing ground
_____ Filter fabric in place
_____ Stone sized as per plan and uniformly placed at the thickness specified

IX. Vegetative Stabilization

_____ Approved seed mixture or sod
_____ Proper surface preparation and required soil amendments
_____ Excelsior mat or other stabilization materials, as per plan

X. Miscellaneous

_____ Toe drain
_____ Temporary dewatering device installed as per plan with appropriate fabric, stone size and perforations if included
_____ Drain for ponds having a permanent pool
_____ Trash rack/anti-vortex device secured to outlet structure
_____ Trash protection for low flow pipes, orifices, etc.
_____ Fencing (when required)
_____ Access road
_____ Set aside area for clean-out maintenance

APPENDIX 6-4

Stormwater/Sediment Pond Typical Sequence of Construction for Embankment Ponds with Riser/Barrel Outlet Structures for Developers and Contractors

Stormwater/Sediment Pond
Typical Sequence of Construction for Embankment Ponds with Riser/Barrel Outlet Structures for Developers and Contractors

(Developed by Randy Greer, Environmental Engineer
Delaware Department of Natural Resources and Environmental Control
Sediment and Stormwater Program)

1. NOTIFY PLAN REVIEW/CONSTRUCTION REVIEW AGENCY AS REQUIRED

   a. Arrange the preconstruction meeting
   b. Clear up any questions regarding the approved plan

2. PRE-CONSTRUCTION MEETING WITH CONSTRUCTION REVIEW AGENCY

   a. Review the site plan and layout and discuss any problems or changes needed to the plan
   b. Obtain approvals for the plan changes from the appropriate inspection or plan review agency
   c. Discuss the stages of construction which notification to the construction review agency is needed

3. SITE LAYOUT

   a. Make sure site layout agrees with the plan
   b. Check elevation of the proposed outfall structure
   c. Physically mark any areas not to be disturbed, such as limit of disturbance, wetlands, property lines, etc.

4. INSTALL PERIMETER EROSION AND SEDIMENT CONTROLS

   a. Sediment controls will be needed at the downstream perimeter during the clearing and grubbing for the pond wherever sediment may leave the site.

5. INSTALL TEMPORARY CHANNEL DIVERSION

   a. Divert clean water flow away from pond area
   b. Stabilize the diversion

6. CLEAR AND GRUB THE POND AREA

7. REMOVE TOPSOIL FROM THE POND AREA

   a. Stockpile the soil in an approved location
   b. Stabilize the stockpile area

8. FACILITY STAKEOUT

   a. Stakeout centerline of embankment, outside and inside toe of slopes

9. CORE TRENCH/EMBANKMENT AREA

a. Arrange to meet the site reviewer to discuss location of core trench
b. If core trench is needed, determine where material will come from before trench is opened.
c. Make arrangements for de-watering of the core trench if necessary
d. Excavate for core trench
e. Fill core trench with suitable material assuring proper compaction to existing ground elevation

10. CONSTRUCT OUTFALL CHANNEL

a. Rock outlet protection with filter cloth
b. Remaining channel constructed and stabilized

11. INSTALL BARREL WITH ANTI-SEEP COLLARS

a. This should be done BEFORE any embankment work
b. Prepare the bedding for the barrel
c. Place barrel and anti-seep collars checking pipe grade
d. Watertight pipe connections to be checked
e. Backfill of barrel with particular attention to the compaction requirements. All structural backfill shall be completely free of rocks and other objectionable material

12. RISER PLACEMENT

a. Check riser structure for conformance to specifications
b. Check elevation of structure
c. Set riser and pour concrete riser base

13. INSTALL ANY EROSION CONTROL STRUCTURES REQUIRED

14. CONSTRUCT REMAINING CORE AND EMBANKMENT

a. Most impervious material placed in core of embankment
b. Material should be checked and approved for suitability
c. Compact the embankment according to specifications
d. Check UNSETTLED elevation and top width of embankment
e. Stabilize embankment

15. DIVERT FLOWS INTO PIPE SYSTEM

16. CONSTRUCT EMERGENCY SPILLWAY

a. If earth spillway, construct in undisturbed ground
b. Check elevation of control section and exit channel

17. INSTALL INFLOW CHANNELS

a. Stabilize according to plan including pipe outfalls into pond

18. COMPLETE EXCAVATION OF POND TO FINAL GRADE

19. VEGETATIVELY STABILIZE ALL DISTURBED AREAS

20. COMPLETE POND CONVERSION

    a. Requires approval of inspector to convert from sediment to stormwater control
    b. Properly de-water the pond in an approved manner
    c. Remove accumulated sediment and restore pond to design grade. Complete final stabilization
    d. Make any structural modifications to the riser for permanent function

APPENDIX 6-5

Construction Checklists
Infiltration Practices

Basins (Appendix 6-5A)
Trenches (Appendix 6-5B)
Dry Wells (Appendix 6-5C)
Paving (Appendix 6-5D)
Swales (Appendix 6-5E)

Infiltration Basin Construction Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date _________________ Time _____________________

Project ____

Location _____________________________________

Individual Contacted ____________________________

Site Status __________________ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	________	________
Area stabilized	________	________
2. Excavation		
Size and location	________	________
Side slope stable	________	________
Soil Permeability	________	________
Groundwater/Bedrock	________	________
3. Embankment		
Cut-off trench	________	________
Fill material	________	________
4. Final Excavation		
Drainage area stabilized	________	________
Sediment removed from facility	________	________
Basin floor tilled	________	________
Facility stabilized	________	________
5. Final Inspection		
Pretreatment facility in place	________	________
Inlets/outlets	________	________
Site stabilization	________	________
Access to facility provided	________	________

Action to be taken:

No action necessary. Continue routine inspections ___________
Correct noted site deficiencies by ________________________
1st notice _________
2nd notice ________
Submit plan modifications as noted in written comments by ________________________
Notice to Comply issued ____________
Final inspection, project completed ____________

Infiltration Trench Construction Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date ________________ Time ____________________

Project ____

Location ____________________________________

Individual Contacted ___________________________

Site Status _________________ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	________	________
Area stabilized	________	________
2. Excavation		
Size and location	________	________
Side slope stable	________	________
Soil Permeability	________	________
Groundwater/Bedrock	________	________
3. Filter Fabric Placement		
Fabric specification	________	________
Placed on bottom, sides, and top	________	________
4. Aggregate Material		
Size as specified	________	________
Clean/washed material	________	________
Placed properly	________	________
5. Observation Well		
Pipe size	________	________
Removable cap/footplate	________	________
Initial depth = _____ ft.	________	________
6. Final Inspection		
Pretreatment facility in place	________	________
Stabilization	________	________
Outlet	________	________

Action to be taken:

No action necessary. Continue routine inspections ___________

Correct noted site deficiencies by ________________________

1st notice _________

2nd notice ________

Submit plan modifications as noted in written comments by ________________________

Notice to Comply issued ____________

Final inspection, project completed ____________

Infiltration Drywell Construction Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date ________________ Time ____________________

Project ____

Location ___________________________________

Individual Contacted ___________________________

Site Status _________________ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	________	________
Area stabilized	________	________
2. Excavation		
Size and location	________	________
Side slope stable	________	________
Soil Permeability	________	________
Groundwater/Bedrock	________	________
3. Filter Fabric Placement		
Fabric specification	________	________
Placed on bottom, sides, and top	________	________
4. Aggregate Material		
Size as specified	________	________
Clean/washed material	________	________
Placed properly	________	________
5. Observation Well/roof leader		
Pipe size	________	________
Removable cap/footplate	________	________
Initial depth = _____ ft.	________	________
6. Final Inspection		
Pretreatment facility in place	________	________
Debris/gutter screens	________	________
Stabilization	________	________
Outlet	________	________

Action to be taken:

No action necessary. Continue routine inspections ___________

Correct noted site deficiencies by ________________________

1st notice _________

2nd notice ________

Submit plan modifications as noted in written comments by _________________________

Notice to Comply issued ____________

Infiltration Paving Construction Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date ________________ Time ____________________

Project ____

Location ___________________________________

Individual Contacted ___________________________

Site Status _________________ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	____________	____________
Area stabilized	____________	____________
2. Excavation		
Size and location	____________	____________
Side slope stable	____________	____________
Soil Permeability	____________	____________
Groundwater/Bedrock	____________	____________
3. Filter Fabric Placement		
Fabric specification	____________	____________
Placed on bottom, sides, and top	____________	____________
4. Aggregate Base Course		
Size as specified	____________	____________
Clean/washed material	____________	____________
Placed properly	____________	____________
5. Aggregate Filter Course		
Size	____________	____________
Clean/washed material	____________	____________
Placed Properly	____________	____________
6. Porous Surface Course		
Proper temperature/compaction	____________	____________
7 Final Inspection		
Smooth Surface & Transition	____________	____________
Test section	____________	____________
Final stabilization	____________	____________

Action to be taken:

No action necessary. Continue routine inspections ___________

Correct noted site deficiencies by ________________________

1st notice _________

2nd notice ________

Submit plan modifications as noted in written comments by _________________________

Notice to Comply issued ____________

Infiltration Swale Construction Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date ________________ Time ____________________

Project ____

Location ___________________________________

Individual Contacted __________________________

Site Status _________________ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	________	________
Area stabilized	________	________
2. Excavation		
Size and location	________	________
Side slope stable	________	________
Soil Permeability	________	________
Groundwater/Bedrock	________	________
3. Check dams		
Dimensions	________	________
Compaction	________	________
4. Final Inspection		
Dimensions	________	________
Check dams	________	________
Proper outlet	________	________
Effective stabilization	________	________

Action to be taken:

- No action necessary. Continue routine inspections ___________
- Correct noted site deficiencies by ________________________
  - 1st notice _________
  - 2nd notice ________
- Submit plan modifications as noted in written comments by _________________________
- Notice to Comply issued ____________
- Final inspection, project completed ____________

APPENDIX 6-6

Construction Checklist for Filtration Practices

Filtration Facility Construction Inspection Report Form

Date ________________ Time ____________________

Project ____

Location ___________________________________

Individual Contacted __________________________

Site Status _________________ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	________	________
Facility area cleared	________	________
Facility location staked out	________	________
2. Excavation		
Size and location	________	________
Side slopes stable	________	________
Foundation cleared of debris	________	________
Foundation area compacted	________	________
3. Structural Components		
Dimensions and materials	________	________
Forms adequately sized	________	________
Concrete meets standards	________	________
Prefabricated joints sealed	________	________
Underdrains (size, materials)	________	________
4. Completed Facility Components		
24 hour water filled test	________	________
Contributing area stabilized	________	________
Filter material per specification	________	________
Underdrains installed to grade	________	________
5. Final Inspection		
Dimensions	________	________
Structural Components	________	________
Proper outlet	________	________
Effective site stabilization	________	________

Action to be taken:

No action necessary. Continue routine inspections ___________

Correct noted site deficiencies by ________________________

1st notice _________

2nd notice ________

Submit plan modifications as noted in written comments by _________________________

Notice to Comply issued ____________

Final inspection, project completed ____________

APPENDIX 6-7

Construction Checklist
for
Biofiltration Practices

Biofiltration Construction Inspection Report Form

Date ________________ Time ____________________

Project ____

Location ___________________________________

Individual Contacted ___________________________

Site Status _________________ (active, inactive, completed)

1. Pre-construction

	Satisfactory	Unsatisfactory
Runoff diverted	____	____
Facility area cleared	____	____
Facility location staked out	____	____
Facility not in heavily shaded area	____	____
2. Excavation		
Size and location	____	____
Lateral slopes completely level	____	____
Longitudinal slopes within design range	____	____
3. Check dams and Level Spreaders		
Dimensions, spacing, and materials	____	____
Compaction	____	____
Level spreaders are completely level	____	____
4. Structural Components		
Inlets and outlets installed correctly	____	____
Flow bypasses installed correctly	____	____
Pretreatment devices installed	____	____
Curb cuts installed per plans	____	____
5. Vegetation		
Complies with planting specs.	____	____
Topsoil adequate in composition and placement	____	____
Adequate erosion control measures in place	____	____
4. Final Inspection		
Dimensions	____	____
Check dams and level spreaders	____	____
Proper outlet	____	____
Effective stand of vegetation and stabilization	____	____
Construction generated sediments removed	____	____

Action to be taken:

No action necessary. Continue routine inspections ___________
Correct noted site deficiencies by ________________________
1st notice _________
2nd notice ________
Submit plan modifications as noted in written comments by _________________________
Notice to Comply issued ____________
Final inspection, project completed ____________

STORMWATER MANAGEMENT SYSTEM
INSPECTION FORMS

FROM:
OPERATION, MAINTENANCE, AND MANAGEMENT OF STORMWATER MANAGEMENT SYSTEMS

PUBLISHED BY:
WATERSHED MANAGEMENT INSTITUTE, INC.

In cooperation with:
Office of Water
U. S. Environmental Protection Agency
Washington D. C

Watershed Management Institute
P.O. Box 14
Ingleside, Maryland 21644
410/758-2731
Fax: 410/758-0386

Watershed Management Institute
410 White Oak Drive
Crawfordville, Florida 32327
850/926-5310
Fax: 850/926-1534

STORMWATER MANAGEMENT SYSTEM INSPECTION FORMS

From CHAPTER 6: CONSTRUCTION INSPECTION of *Operation, Maintenance, and Management of Stormwater Management Systems*

From CHAPTER 7: INSPECTION AND MAINTENANCE AFTER CONSTRUCTION of *Operation, Maintenance, and Management of Stormwater Management Systems*

The handbook *Operation, Maintenance, and Management of Stormwater Management Systems* was produced by the Watershed Management Institute, Inc. in cooperation with the United States Environmental Protection Agency, Office of Water, through Cooperative Agreement CX823621-01-0. The contents do not necessarily reflect the views or policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

APPENDICES
FROM CHAPTER 6

Construction Inspection Forms
for
Stormwater Management
Practices

APPENDIX 6-1

Preconstruction Inspection Meeting Topics Form

State of New Jersey
Department of Environmental Protection
Stormwater Management Facility Maintenance Manual

Example Preconstruction Meeting Topics

A. GENERAL INFORMATION

1. Attendance
2. Purpose of project and background information
3. Emergency telephone numbers
4. Construction photograph requirements
5. Project sign requirements
6. Starting date
7. Review of contract documents, including insurance certifications, bonds and subcontractors documents
8. Field office requirements
9. Responsibility for notification of affected property owners and residents
10. Chain of command for communications and correspondence
11. Construction schedules
12. Key personnel and their degree of involvement in the project (inspector, owner, engineer, agencies, etc.)

B. POLICE AND FIRE DEPARTMENT CONCERNS

1. Traffic control
2. Barricades and signs conforming to the uniform manual
3. Noise ordinance considerations
4. Working hours, including weekend and holidays
5. Vandalism and preventative measures
6. Flagmen and traffic control officers
7. Equipment storage and vehicle parking
8. Emergency vehicle access
9. Underground tank locations and precautionary construction procedures
10. Storage and use of hazardous materials

C. UTILITIES

1. Utility locations and mark-outs
2. Coordination of utility relocations
3. Emergency phone numbers of utility companies

D. FUNDING AND PAYMENTS

1. Funding sources and availability
2. Procedures and dates for payment estimates
3. Dates for payments to contractor
4. Breakdown of lump sum items for partial payment
5. Policy for payment for materials on site at the close of a payment period
6. Retained monies during and after construction

7. Requirements of funding agencies

E. CHANGE ORDERS AND EXTRA CLAIMS

1. Requirements for additional work and submittal of change orders
2. Procedures and schedule for review and recommendations of change orders
3. Procedures for negotiating extra claims and change orders

F. CONSTRUCTION ACCESS AND EASEMENTS

1. Easement locations and maps
2. Responsibility for locating and staking easements
3. Available survey data for the site
4. Access requirements and staging areas
5. Easement restrictions and restoration requirements

G. CONSTRUCTION DETAILS

1. Unique or complex aspects of the project
2. Testing laboratories and sampling procedures
3. Cold and hot weather protection measures
4. Blasting requirements
5. Dump site location for construction related materials
6. Shop drawing requirements and review procedures
7. Specific construction techniques and procedures
8. Review of technical section of the specifications

H. PERMITS

1. Status of all required federal, state, and local permits
2. Permit restrictions and conditions
3. Start-of-work notifications

APPENDIX 6-2

General Site Inspection and Notice to Comply Forms

Construction Inspection Report Form

(adapted from State of Delaware Sediment and Stormwater Program)

Date ________________ Time ____________________

Project ____

Location ___________________________________

Individual Contacted __________________________

Weather Conditions ___________________________

Site Status _________________ (active, inactive, completed)

Site Conditions:

acceptable ________
Unacceptable ________
In compliance with approved plan _________
Approved plan is adequate for the site _________

Written Comments:

____
____
____
____
____
____
____

Action to be taken:

No action necessary. Continue routine inspections ___________
Correct noted site deficiencies by ________________________
1st notice _________
2nd notice ________
Submit plan modifications as noted in written comments by _________________________
Notice to Comply issued ____________
Final inspection, project completed ____________
Other ____

________________________ ________________________
Received by Inspector

I acknowledge receipt of this inspection report. My signature does not imply agreement or disagreement with its content

Questions or comments regarding this inspection report should be directed to the appropriate inspection agency the appropriate address and phone number.

white: developer/contractor yellow: file pink: legal/enforcement

Notice to Comply Inspection Report Form

(adapted from State of Delaware Sediment and Stormwater Program)

Date ____________

To: ____

Address: ____

____

Project/Site/Contract Name ____

An inspection of the above referenced project on _________________________(Date) revealed that the site is not in compliance with the approved Sediment Control and Stormwater Management Plan, approved Plan amendments, Law, or Regulations, and the following violations exist:

____

____

____

____

____

____

____

____

____

____

Notice is hereby given that the above violations shall be corrected in accordance with the approved Sediment Control and Stormwater Management Plan, approved Plan amendments, Law, or Regulations on or before _____________________________ (Date). The site will be reinspected at that time to determine if the site has been brought into compliance with the approved Plan, approved Plan amendments, Law, or Regulations.

Failure to comply with this notice will result in the initiation of legal action by the Department in order to bring the site into compliance with the approved Plan, approved Plan amendments, Law, or Regulations.

_____________________________ Received by

_____________________________ Inspector

I hereby acknowledge receipt of this notice to comply. My signature does not imply agreement or disagreement with its content

Questions or comments regarding this inspection report should be directed to the appropriate inspection agency at the appropriate address and phone number

white: developer/contractor   yellow: file   pink: legal/enforcement

APPENDIX 6-3

Sediment/Stormwater Management Basin Construction Inspection Checklist

Sediment/Stormwater Management Basin Construction Checklist

For Permanent structures per Delaware NRCS Pond Code 378 and Delaware Sediment and Stormwater Regulations
(Developed by Randy Greer, Environmental Engineer)

KEY

_✓__ Item meets standard
_✗_ _ Item not acceptable
_N/A_ Item not applicable
_C___ Item requires engineer's certification

PROJECT INFORMATION

Project ID: __________________
Contractor: _________________
Inspector: __________________
Date(s): ___________________

I. Materials and Equipment

______ Pipe and appurtenances on-site prior to construction and dimensions checked.
- ______ 1. Material (including protective coating, if specified)
- ______ 2. Diameter
- ______ 3. Dimensions of metal riser or pre-cast concrete outlet structure
- ______ 4. Required dimensions between water control structures (orifices, weirs, etc.) are in accordance with approved plans
- ______ 5. Barrel stub for prefabricated pipe structures at proper angle for design barrel slope
- ______ 6. Number and dimensions of prefabricated anti-seep collars
- ______ 7. Watertight connectors and gaskets
- ______ 8. Outlet drain valve

______ Appropriate compaction equipment available, including hand and small power tamps
______ Project benchmark near pond site
______ Equipment for temporary de-watering

II. Subgrade Preparation

______ Area beneath embankment stripped of all vegetation, topsoil, and organic matter
______ Cut-off trench excavated a minimum of 4 feet below subgrade and minimum 4 feet below proposed pipe invert, with side slopes no steeper than 1:1
______ Impervious material used to backfill cut-off trench

III. Pipe Spillway Installation

______ Method of installation detailed on plans

A. Bed preparation
- ______ Installation trench excavated with 1:1 side slopes
- ______ Stable, uniform, dry subgrade of relatively impervious material *(If subgrade is wet, contractor shall have defined steps before proceeding with installation)*
- ______ Invert at proper elevation and grade

B. Pipe placement

_____ Metal/Plastic pipe

- _____ 1. Watertight connectors and gaskets properly installed
- _____ 2. Anti-seep collars properly spaced and having watertight connections to pipe
- _____ 3. Backfill placed and tamped by hand under "haunches" of pipe
- _____ 4. Remaining backfill placed in max. 8" lifts using small power tamping equipment until 2 feet cover over pipe is reached

_____ Concrete pipe

- _____ 1. Pipe set on blocks or concrete slab for pouring of low cradle
- _____ 2. Pipe installed with rubber gasket joints with no spalling in gasket interface area
- _____ 3. Excavation for lower half of anti-seep collar(s) with reinforcing steel set
- _____ 4. Entire area where anti-seep collar(s) will come in contact with pipe coated with mastic or other approved waterproof sealant
- _____ 5. Low cradle and bottom half of anti-seep collar installed as monolithic pour and of an approved mix
- _____ 6. Upper half of anti-seep collar(s) formed with reinforcing steel set
- _____ 7. Concrete for collar of an approved mix and vibrated into place. (Protected from freezing while curing, if necessary)
- _____ 8. Forms stripped and collar inspected for honeycomb prior to backfilling. Parge if necessary

C. Backfilling

- _____ Fill placed in maximum 8" lifts
- _____ Backfill taken minimum 2 feet above top of anti-seep collar elevation before traversing with heavy equipment

IV. Riser/Outlet Structure Installation

A. Metal riser

- _____ Riser base excavated or formed on stable subgrade to design dimensions
- _____ Embedded section of aluminum or aluminized pipe to be painted with zinc chromate or equivalent on **inside and outside** surfaces
- _____ Set on blocks to design elevations and plumbed
- _____ Reinforcing bars placed at right angles and projecting into sides of riser
- _____ Concrete poured so as to fill inside of riser to invert of barrel

B. Pre-cast concrete structure

- _____ Dry and stable subgrade
- _____ Riser base set to design elevation
- _____ If more than one section, no spalling in gasket interface area; gasket or approved caulking material placed securely
- _____ Watertight and structurally sound collar or gasket joint where structure connects to pipe spillway

C. Poured concrete structure

- _____ Footing excavated or formed on stable subgrade, to design dimensions with reinforcing steel set
- _____ Structure formed to design dimensions, with reinforcing steel set as per plan
- _____ Concrete of an approved mix and vibrated into place. (Protected from freezing while curing, if necessary)
- _____ Forms stripped and structure inspected for "honeycomb" prior to backfilling. Parge if necessary

V. Embankment Construction

A. Fill material
- _____ Soil engineer's test
- _____ Visual test by inspector

B. Compaction
- _____ Soil engineer's test
- _____ Visual test by inspector

C. Embankment
- _____ Fill placed in maximum 8" lifts and compacted with appropriate equipment
- _____ Constructed to design cross-section, side slopes and top width
- _____ Constructed to design elevation plus allowance for settlement

VI. Impounded Area Construction

- _____ Excavated/graded to design contours and side slopes
- _____ Inlet pipes have adequate outfall protection
- _____ Forebay(s)
- _____ Wet pond requirements
  - _____ 1. 10 feet reverse slope bench one foot above normal pool elevation
  - _____ 2. 10 feet wide level bench one foot below normal pool elevation

VII. Earth Emergency Spillway Construction

- _____ Spillway located in cut or structurally stabilized with riprap, gabions, concrete, etc.
- _____ Excavated to proper cross-section, side slopes and bottom width
- _____ Entrance channel, crest, and exit channel constructed to design grades and elevations

VIII. Outlet Protection

A. End section
- _____ Securely in place and properly backfilled

B. Endwall
- _____ Footing excavated or formed on stable subgrade, to design dimensions and reinforcing steel set, if specified
- _____ Endwall formed to design dimensions with reinforcing steel set as per plan
- _____ Concrete of an approved mix and vibrated into place. (Protected from freezing, if necessary
- _____ Forms stripped and structure inspected for "honeycomb" prior to backfilling. Parge if necessary

C. Riprap apron/channel
- _____ Apron/channel excavated to design cross-section with proper transition to existing ground
- _____ Filter fabric in place
- _____ Stone sized as per plan and uniformly placed at the thickness specified

IX. Vegetative Stabilization

_____ Approved seed mixture or sod
_____ Proper surface preparation and required soil amendments
_____ Excelsior mat or other stabilization materials, as per plan

X. Miscellaneous

_____ Toe drain
_____ Temporary dewatering device installed as per plan with appropriate fabric, stone size and perforations if included
_____ Drain for ponds having a permanent pool
_____ Trash rack/anti-vortex device secured to outlet structure
_____ Trash protection for low flow pipes, orifices, etc.
_____ Fencing (when required)
_____ Access road
_____ Set aside area for clean-out maintenance

APPENDIX 6-4

Sediment/Stormwater Pond
Typical Sequence of Construction
for
Embankment Ponds with
Riser/Barrel Outlet Structures
for
Developers and Contractors

Stormwater/Sediment Pond
Typical Sequence of Construction for Embankment Ponds with Riser/Barrel Outlet Structures for Developers and Contractors

(Developed by Randy Greer, Environmental Engineer
Delaware Department of Natural Resources and Environmental Control
Sediment and Stormwater Program)

1. NOTIFY PLAN REVIEW/CONSTRUCTION REVIEW AGENCY AS REQUIRED

   a. Arrange the preconstruction meeting
   b. Clear up any questions regarding the approved plan

2. PRE-CONSTRUCTION MEETING WITH CONSTRUCTION REVIEW AGENCY

   a. Review the site plan and layout and discuss any problems or changes needed to the plan
   b. Obtain approvals for the plan changes from the appropriate inspection or plan review agency
   c. Discuss the stages of construction which notification to the construction review agency is needed

3. SITE LAYOUT

   a. Make sure site layout agrees with the plan
   b. Check elevation of the proposed outfall structure
   c. Physically mark any areas not to be disturbed, such as limit of disturbance, wetlands, property lines, etc.

4. INSTALL PERIMETER EROSION AND SEDIMENT CONTROLS

   a. Sediment controls will be needed at the downstream perimeter during the clearing and grubbing for the pond wherever sediment may leave the site.

5. INSTALL TEMPORARY CHANNEL DIVERSION

   a. Divert clean water flow away from pond area
   b. Stabilize the diversion

6. CLEAR AND GRUB THE POND AREA

7. REMOVE TOPSOIL FROM THE POND AREA

   a. Stockpile the soil in an approved location
   b. Stabilize the stockpile area

8. FACILITY STAKEOUT

   a. Stakeout centerline of embankment, outside and inside toe of slopes

9. CORE TRENCH/EMBANKMENT AREA

a. Arrange to meet the site reviewer to discuss location of core trench
b. If core trench is needed, determine where material will come from before trench is opened.
c. Make arrangements for de-watering of the core trench if necessary
d. Excavate for core trench
e. Fill core trench with suitable material assuring proper compaction to existing ground elevation

10. CONSTRUCT OUTFALL CHANNEL

a. Rock outlet protection with filter cloth
b. Remaining channel constructed and stabilized

11. INSTALL BARREL WITH ANTI-SEEP COLLARS

a. This should be done BEFORE any embankment work
b. Prepare the bedding for the barrel
c. Place barrel and anti-seep collars checking pipe grade
d. Watertight pipe connections to be checked
e. Backfill of barrel with particular attention to the compaction requirements. All structural backfill shall be completely free of rocks and other objectionable material

12. RISER PLACEMENT

a. Check riser structure for conformance to specifications
b. Check elevation of structure
c. Set riser and pour concrete riser base

13. INSTALL ANY EROSION CONTROL STRUCTURES REQUIRED

14. CONSTRUCT REMAINING CORE AND EMBANKMENT

a. Most impervious material placed in core of embankment
b. Material should be checked and approved for suitability
c. Compact the embankment according to specifications
d. Check UNSETTLED elevation and top width of embankment
e. Stabilize embankment

15. DIVERT FLOWS INTO PIPE SYSTEM

16. CONSTRUCT EMERGENCY SPILLWAY

a. If earth spillway, construct in undisturbed ground
b. Check elevation of control section and exit channel

17. INSTALL INFLOW CHANNELS

a. Stabilize according to plan including pipe outfalls into pond

18. COMPLETE EXCAVATION OF POND TO FINAL GRADE

19. VEGETATIVELY STABILIZE ALL DISTURBED AREAS

20. COMPLETE POND CONVERSION

    a. Requires approval of inspector to convert from sediment to stormwater control
    b. Properly de-water the pond in an approved manner
    c. Remove accumulated sediment and restore pond to design grade. Complete final stabilization
    d. Make any structural modifications to the riser for permanent function

APPENDIX 6-5

Construction Checklists for Infiltration Practices

Basins (Appendix 6-5A)
Trenches (Appendix 6-5B)
Dry Wells (Appendix 6-5C)
Paving (Appendix 6-5D)
Swales (Appendix 6-5E)

Infiltration Basin Construction Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date ________________ Time ____________________

Project ____

Location ___________________________________

Individual Contacted __________________________

Site Status _________________ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	___	___
Area stabilized	___	___
2. Excavation		
Size and location	___	___
Side slope stable	___	___
Soil Permeability	___	___
Groundwater/Bedrock	___	___
3. Embankment		
Cut-off trench	___	___
Fill material	___	___
4. Final Excavation		
Drainage area stabilized	___	___
Sediment removed from facility	___	___
Basin floor tilled	___	___
Facility stabilized	___	___
5. Final Inspection		
Pretreatment facility in place	___	___
Inlets/outlets	___	___
Site stabilization	___	___
Access to facility provided	___	___

Action to be taken:

No action necessary. Continue routine inspections ___________
Correct noted site deficiencies by ________________________
1st notice _________
2nd notice ________
Submit plan modifications as noted in written comments by ________________________
Notice to Comply issued ____________
Final inspection, project completed ____________

Infiltration Trench Construction Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date _________________ Time _____________________

Project ____

Location _____________________________________

Individual Contacted ____________________________

Site Status __________________ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	____________	____________
Area stabilized	____________	____________
2. Excavation		
Size and location	____________	____________
Side slope stable	____________	____________
Soil Permeability	____________	____________
Groundwater/Bedrock	____________	____________
3. Filter Fabric Placement		
Fabric specification	____________	____________
Placed on bottom, sides, and top	____________	____________
4. Aggregate Material		
Size as specified	____________	____________
Clean/washed material	____________	____________
Placed properly	____________	____________
5. Observation Well		
Pipe size	____________	____________
Removable cap/footplate	____________	____________
Initial depth = _____ ft.	____________	____________
6. Final Inspection		
Pretreatment facility in place	____________	____________
Stabilization	____________	____________
Outlet	____________	____________

Action to be taken:

No action necessary. Continue routine inspections ___________

Correct noted site deficiencies by ________________________

1st notice _________

2nd notice ________

Submit plan modifications as noted in written comments by _________________________

Notice to Comply issued ____________

Final inspection, project completed ____________

Infiltration Drywell Construction Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date ________________ Time ____________________

Project ____

Location ___________________________________

Individual Contacted __________________________

Site Status _________________ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	______	______
Area stabilized	______	______
2. Excavation		
Size and location	______	______
Side slope stable	______	______
Soil Permeability	______	______
Groundwater/Bedrock	______	______
3. Filter Fabric Placement		
Fabric specification	______	______
Placed on bottom, sides, and top	______	______
4. Aggregate Material		
Size as specified	______	______
Clean/washed material	______	______
Placed properly	______	______
5. Observation Well/roof leader		
Pipe size	______	______
Removable cap/footplate	______	______
Initial depth = _____ ft.	______	______
6. Final Inspection		
Pretreatment facility in place	______	______
Debris/gutter screens	______	______
Stabilization	______	______
Outlet	______	______

Action to be taken:

No action necessary. Continue routine inspections ___________

Correct noted site deficiencies by _______________________

1st notice _________

2nd notice ________

Submit plan modifications as noted in written comments by ________________________

Notice to Comply issued ____________

Infiltration Paving Construction Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date ________________ Time ____________________

Project ____

Location ________________________________

Individual Contacted __________________________

Site Status _________________ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	________	________
Area stabilized	________	________
2. Excavation		
Size and location	________	________
Side slope stable	________	________
Soil Permeability	________	________
Groundwater/Bedrock	________	________
3. Filter Fabric Placement		
Fabric specification	________	________
Placed on bottom, sides, and top	________	________
4. Aggregate Base Course		
Size as specified	________	________
Clean/washed material	________	________
Placed properly	________	________
5. Aggregate Filter Course		
Size	________	________
Clean/washed material	________	________
Placed Properly	________	________
6. Porous Surface Course		
Proper temperature/compaction	________	________
7. Final Inspection		
Smooth Surface & Transition	________	________
Test section	________	________
Final stabilization	________	________

Action to be taken:

No action necessary. Continue routine inspections ___________
Correct noted site deficiencies by _______________________
1st notice _________
2nd notice ________
Submit plan modifications as noted in written comments by ________________________
Notice to Comply issued ____________ Final inspection, project completed ____________

Infiltration Swale Construction Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date ________________ Time ____________________

Project ____

Location ___________________________________

Individual Contacted __________________________

Site Status _________________ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	___________	___________
Area stabilized	___________	___________
2. Excavation		
Size and location	___________	___________
Side slope stable	___________	___________
Soil Permeability	___________	___________
Groundwater/Bedrock	___________	___________
3. Check dams		
Dimensions	___________	___________
Compaction	___________	___________
4. Final Inspection		
Dimensions	___________	___________
Check dams	___________	___________
Proper outlet	___________	___________
Effective stabilization	___________	___________

Action to be taken:

- No action necessary. Continue routine inspections ___________
- Correct noted site deficiencies by ________________________
    - 1st notice _________
    - 2nd notice ________
- Submit plan modifications as noted in written comments by _________________________
- Notice to Comply issued ____________
- Final inspection, project completed ____________

APPENDIX 6-6

Construction Checklist for Filtration Practices

Filtration Facility Construction Inspection Report Form

Date ________________ Time ____________________

Project ____

Location ____________________________________

Individual Contacted ___________________________

Site Status _________________ (active, inactive, completed)

	Satisfactory	Unsatisfactory
1. Pre-construction		
Runoff diverted	____________	____________
Facility area cleared	____________	____________
Facility location staked out	____________	____________
2. Excavation		
Size and location	____________	____________
Side slopes stable	____________	____________
Foundation cleared of debris	____________	____________
Foundation area compacted	____________	____________
3. Structural Components		
Dimensions and materials	____________	____________
Forms adequately sized	____________	____________
Concrete meets standards	____________	____________
Prefabricated joints sealed	____________	____________
Underdrains (size, materials)	____________	____________
4. Completed Facility Components		
24 hour water filled test	____________	____________
Contributing area stabilized	____________	____________
Filter material per specification	____________	____________
Underdrains installed to grade	____________	____________
5. Final Inspection		
Dimensions	____________	____________
Structural Components	____________	____________
Proper outlet	____________	____________
Effective site stabilization	____________	____________

Action to be taken:

No action necessary. Continue routine inspections ___________

Correct noted site deficiencies by ________________________

1st notice _________

2nd notice ________

Submit plan modifications as noted in written comments by _________________________

Notice to Comply issued ____________

Final inspection, project completed ____________

APPENDIX 6-7

Construction Checklist
for
Biofiltration Practices

Biofiltration Construction Inspection Report Form

Date ________________ Time ____________________

Project ____

Location ___________________________________

Individual Contacted ___________________________

Site Status _________________ (active, inactive, completed)

1. Pre-construction

	Satisfactory	Unsatisfactory
Runoff diverted	____________	____________
Facility area cleared	____________	____________
Facility location staked out	____________	____________
Facility not in heavily shaded area	____________	____________

2. Excavation

Size and location	____________	____________
Lateral slopes completely level	____________	____________
Longitudinal slopes within design range	____________	____________

3. Check dams and Level Spreaders

Dimensions, spacing, and materials	____________	____________
Compaction	____________	____________
Level spreaders are completely level	____________	____________

4. Structural Components

Inlets and outlets installed correctly	____________	____________
Flow bypasses installed correctly	____________	____________
Pretreatment devices installed	____________	____________
Curb cuts installed per plans	____________	____________

5. Vegetation

Complies with planting specs.	____________	____________
Topsoil adequate in composition and placement	____________	____________
Adequate erosion control measures in place	____________	____________

4. Final Inspection

Dimensions	____________	____________
Check dams and level spreaders	____________	____________
Proper outlet	____________	____________
Effective stand of vegetation and stabilization	____________	____________
Construction generated sediments removed	____________	____________

Action to be taken:

No action necessary. Continue routine inspections ___________
Correct noted site deficiencies by _______________________
1st notice _________
2nd notice ________
Submit plan modifications as noted in written comments by ________________________
Notice to Comply issued ____________
Final inspection, project completed ____________

APPENDICES
FROM CHAPTER 7

Operation, Maintenance, and Management Inspection Forms for Stormwater Management Practices

APPENDIX 7-1

Operation, Maintenance, and Management Inspection Checklist for Ponds

Operation and Maintenance Inspection Report for Stormwater Management Ponds
(Adapted from Anne Arundel County, Maryland)

Inspector Name ____________________________ Community ____________________________
Inspection Date ____________________________ Address ____________________________
Stormwater Pond ____________________________
Normal Pool _______ ____________________________
Normally Dry _______ Watershed ____________________________

Items inspected	Checked Yes	Checked No	Maintenance Needed Yes	Maintenance Needed No	Inspection Frequency	Remarks
I, Pond components						
A. Embankment and Emergency spillway					A,S	
1. Vegetation and ground Cover adequate						
2. Embankment erosion						
3. Animal burrows						
4. Unauthorized plantings						
5. Cracking, bulging, or sliding of dam						
a. Upstream face						
b. Downstream face						
c. At or beyond toe Upstream						
Downstream						
d. Emergency spillway						
6. Pond, toe & chimney drains clear and functioning						
7. Seeps/leaks on downstream face						
8. Slope protection or riprap failures						
9. Vertical and horizontal alignment of top of dam as per "As-Built" plans						
10. Emergency spillway clear of obstructions and debris						
11. Other (specify)						
B. Riser and principal spillway					A	
Type: Reinforced concrete ___ Corrugated pipe ___ Masonry ___						
1. Low flow orifice obstructed						
2. Low flow trash rack						
a. Debris removal necessary						
b. Corrosion control						
3. Weir trash rack maintenance						
a. Debris removal necessary						
b. Corrosion control						

Inspection Frequency Key A=Annual, M=Monthly, S=After major storm

Items inspected	Checked Yes	Checked No	Maintenance Needed Yes	Maintenance Needed No	Inspection Frequency	Remarks
4. Excessive sediment accumulation inside riser						
5. Concrete/Masonry condition Riser and barrels						
a. Cracks or displacement						
b. Minor spalling (<1")						
c. Major spalling (rebars exposed)						
d. Joint failures						
e. Water tightness						
6. Metal pipe condition						
7. Control valve						
a. Operational/exercised						
b. Chained and locked						
8. Pond drain valve						
a. Operational/exercised						
b. Chained and locked						
9. Outfall channels functioning						
10. Other (specify)						
C. Permanent pool (wet ponds)					M	
1. Undesirable vegetative growth						
2. Floating or floatable debris removal required						
3. Visible pollution						
4. Shoreline problems						
5. Other (specify)						
D. Sediment forebays						
1. Sedimentation noted						
2. Sediment cleanout when depth < 50% design depth						
E. Dry pond areas					M	
1. Vegetation adequate						
2. Undesirable vegetative growth						
3. Undesirable woody vegetation						
4. Low flow channels clear of obstructions						
5. Standing water or wet spots						
6. Sediment and/or trash accumulation						
7. Other (specify)						
F. Condition of outfalls into pond					A,S	
1. Riprap failures						
2. Slope erosion						
3. Storm drain pipes						
4. Endwalls/headwalls						
5. Other (specify)						
G. Other					M	
1. Encroachments on pond or easement area						

Inspection Frequency Key A=Annual, M=Monthly, S=After major storm

Items inspected	Checked Yes	Checked No	Maintenance Needed Yes	Maintenance Needed No	Inspection Frequency	Remarks
2. Complaints from residents (describe on back)						
3. Aesthetics a. grass mowing required						
b. graffiti removal needed						
c. Other (specify)						
4. Any public hazards (specify)						
5. Maintenance access						
H. Constructed wetland areas					A	
1. Vegetation healthy and growing						
2. Evidence of invasive species						
3. Excessive sedimentation in wetland area						

Inspection Frequency Key A=Annual, M=Monthly, S=After major storm

II. Summary

1. Inspectors Remarks: ____

____
____
____
____
____
____
____
____

2. Overall condition of Facility (Check one)

______ Acceptable
______ Unacceptable

3. Dates any maintenance must be completed by:

____
____
____
____

APPENDIX 7-2

Operation, Maintenance, and Management Inspection Checklists for Infiltration Practices:

Basins (Appendix 7-2A)
Trenches (Appendix 7-2B)
Dry Wells (Appendix 7-2C)
Paving (Appendix 7-2D)
Swales (Appendix 7-2E)

Infiltration Basin Maintenance Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date ________________ Time ____________________

Project ____

Location ___________________________________

Individual Conducting the Inspection _______________________ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

Item	Frequency	Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Basin bottom clear of debris		______	______
Inlet clear of debris		______	______
Outlet clear of debris		______	______
Emergency spillway clear of debris		______	______
2. Sediment traps or forebays	(Annual)		
Obviously trapping sediment		______	______
greater than 50% of storage volume remaining		______	______
3. Vegetation	(Monthly)		
mowing done when needed		______	______
Fertilized per specifications		______	______
No evidence of erosion			
4. Dewatering	(Monthly)		
Basin dewaters between storms		______	______
5. Sediment cleanout of basin	(Annual)		
No evidence of sedimentation in basin		______	______
Sediment accumulation does not yet require cleanout		______	______
6. Inlets	(Annual)		
Good condition		______	______
No evidence of erosion		______	______
7. Outlets/overflow spillway	(Annual, After Major Storm)		
Good condition, no need for repair		______	______
No evidence of erosion		______	______
8. Structural repairs	(Annual, After Major Storm)		
Embankment in good repair		______	______
Side slopes are stable		______	______
No evidence of erosion		______	______

Inspection Frequency Key Annual, Monthly, After major storm

		Satisfactory	Unsatisfactory
9. Fences/access repairs	(Annual)		
Fences in good condition		________	________
No damage which would allow undesired entry		________	________
Access point in good condition		________	________
Locks and gate function adequate		________	________

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections ___________
Correct noted facility deficiencies by ______________________

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or improvements.

Site reinspection accomplished on ________________________

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

____

____
Signature of Inspector

Infiltration Trench Maintenance Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date ________________ Time ____________________

Project ____

Location ___________________________________

Individual Conducting the Inspection _______________________ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

Item	Satisfactory	Unsatisfactory
1. Debris cleanout (Monthly)		
Trench surface clear of debris	______	______
Inlet areas clear of debris	______	______
Inflow pipes clear of debris	______	______
Overflow spillway clear of debris	______	______
2. Sediment traps, forebays, or pretreatment swales (Annual)		
Obviously trapping sediment	______	______
greater than 50% of storage volume remaining	______	______
3. Vegetation (Monthly)		
mowing done when needed	______	______
Fertilized per specifications	______	______
No evidence of erosion		
4. Dewatering (Monthly)		
Trench dewaters between storms	______	______
5. Sediment cleanout of trench (Annual)		
No evidence of sedimentation in trench	______	______
Sediment accumulation does not yet require cleanout	______	______
6. Inlets (Annual)		
Good condition	______	______
No evidence of erosion	______	______
7. Outlets/overflow spillway (Annual)		
Good condition, no need for repair	______	______
No evidence of erosion	______	______

Inspection Frequency Key Annual, Monthly, After major storm

	Satisfactory	Unsatisfactory
8. Aggregate repairs (Annual)		
Surface of aggregate clean	________	________
Top layer of stone does not need replacement	________	________
Trench does not need rehabilitation	________	________
9. Vegetated surface (Monthly)		
No evidence of erosion	________	________
Perforated inlet functioning adequately	________	________
Water does not stand on vegetative surface	________	________
Good vegetative cover exists	________	________

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections ___________
Correct noted facility deficiencies by ______________________

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or improvements.

Site reinspection accomplished on ________________________

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

____

____
Signature of Inspector

Infiltration Dry Well Maintenance Inspection Report Form

Date ________________ Time ____________________

Project ____

Location ___________________________________

Individual Conducting the Inspection ________________________ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

Item	Frequency	Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Roof drains and downspouts clean		______	______
2. Vegetation on top of dry well	(Monthly)		
mowing done when needed		______	______
Fertilized per specifications		______	______
No evidence of erosion		______	______
3. Dewatering	(Monthly)		
Dry well dewaters between storms		______	______
4. Inlets	(Annual)		
Good condition of down spouts		______	______
No evidence of deterioration		______	______
Roof gutters drain correctly into dry well		______	______
5. Outlets/overflow spillway	(Annual)		
Good condition, no need for repair		______	______
No evidence of erosion		______	______

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections ___________

Correct noted facility deficiencies by ______________________

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or improvements.

Site reinspection accomplished on ________________________

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

________________________________ ____________________________________

Signature of Inspector

Infiltration Paving Maintenance Inspection Report Form

Date ________________ Time ____________________

Project ____

Location ___________________________________

Individual Conducting the Inspection ________________________ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

	Satisfactory	Unsatisfactory
1. Debris on infiltration paving parking area (Monthly)		
Paving area clean of debris	______	______
2. Vegetation (any buffer areas or pervious areas in drainage area) (Monthly)		
mowing done when needed	______	______
Fertilized per specifications	______	______
No evidence of erosion	______	______
3. Dewatering (Monthly)		
Infiltration paving dewaters between storms	______	______
4. Sediments (Monthly)		
Area clean of sediments	______	______
Area vacuum swept on a periodic basis	______	______
5. Structural condition (Annual)		
No evidence of surface deterioration	______	______
No evidence of rutting or spalling	______	______

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections ___________
Correct noted facility deficiencies by ______________________

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or improvements.

Site reinspection accomplished on ________________________

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

________________________________ ____________________________________
Signature of Inspector

Infiltration Swale Well Maintenance Inspection Report Form

Date ________________ Time ____________________

Project ____

Location ___________________________________

Individual Conducting the Inspection ________________________ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

		Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Swales and contributing areas clean of debris		____	____
2. Vegetation	(Monthly)		
mowing done when needed		____	____
Fertilized per specifications		____	____
No evidence of erosion		____	____
Minimum mowing depth not exceeded		____	____
3. Dewatering	(Monthly)		
Swale dewaters between storms		____	____
4. Check dams or energy dissipators	(Annual, After Major Storm)		
No evidence of flow going around structures		____	____
No evidence of erosion at downstream toe		____	____
5. Sediment deposition	(Annual)		
Swale clean of sediments		____	____
6. Outlets/overflow spillway	(Annual, After Major Storm)		
Good condition, no need for repair		____	____
No evidence of erosion		____	____

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections ____________

Correct noted facility deficiencies by ________________________

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections.

Site reinspection accomplished on __________________________

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

__________________________________ __________________________________

Signature of Inspector

APPENDIX 7-3

Operation, Maintenance and Management Inspection Checklist for Filtration Practices

Filtration Facility Maintenance Inspection Report Form

Date ________________ Time ____________________

Project ____

Location ___________________________________

Individual Conducting the Inspection ______________________ "As Built" Plans available Y/N

Warning: If filtration facility has a watertight cover; be careful regarding the possibility of flammable gases within the facility. Care should be taken lighting a match or smoking while inspecting facilities that are not vented.

Inspection frequency shown in parentheses after item being considered

Item	Frequency	Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Contributing areas clean of debris		________	________
Filtration facility clean of debris		________	________
Inlets and outlets clear of debris		________	________
2. Vegetation	(Monthly)		
Contributing drainage area stabilized		________	________
No evidence of erosion		________	________
Area mowed and clippings removed			
3. Oil and grease	(Monthly)		
No evidence of filter surface clogging		________	________
Activities in drainage area minimize oil & grease entry		________	________
4. Water retention where required	(Monthly)		
Water holding chambers at normal pool		________	________
No evidence of leakage		________	________
5. Sediment deposition	(Annual)		
Filtration chamber clean of sediments		________	________
Water chambers not more than 1/2 full of sediments		________	________
6. Structural components	(Annual)		
No evidence of structural deterioration		________	________
Any grates are in good condition		________	________
No evidence of spalling or cracking of structural parts		________	________
7. Outlets/overflow spillway	(Annual)		
Good condition, no need for repair		________	________
No evidence of erosion (if draining into a natural channel)		________	________

Inspection Frequency Key Annual, Monthly, After major storm

		Satisfactory	Unsatisfactory
8. Overall function of facility	(Annual)		
No evidence of flow bypassing facility		______	______
No noticeable odors outside of facility		______	______

Inspection Frequency Key   Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections ___________
Correct noted facility deficiencies by ______________________

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or repairs.

Site reinspection accomplished on ________________________

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

________________________________   ____________________________________
Signature of Inspector

APPENDIX 7-4

Operation, Maintenance and Management Inspection Checklist for Biofiltration Practices

Biofiltration Facility Maintenance Inspection Report Form

Date ________________ Time ____________________

Project ____

Location ___________________________________

Individual Conducting the Inspection ______________________ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

Item	Frequency	Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Biofilters and contributing areas clean of debris		____	____
No dumping of yard wastes into biofilter		____	____
Litter (branches, etc.) have been removed		____	____
2. Vegetation	(Monthly)		
Plant height not less than design water depth		____	____
Fertilized per specifications		____	____
No evidence of erosion		____	____
Grass height not greater than 6 inches		____	____
Is plant composition according to approved plans		____	____
No placement of inappropriate plants		____	____
3. Dewatering	(Monthly)		
Biofilter dewaters between storms		____	____
No evidence of standing water		____	____
4. Check dams/energy dissipators/sumps	(Annual, After Major Storm)		
No evidence of sediment buildup		____	____
Sumps should not be more than 50% full of sediment		____	____
No evidence of erosion at downstream toe of drop structures		____	____
5. Sediment deposition	(Annual)		
Swale clean of sediments		____	____
Sediments should not be > than 20% of swale design depth		____	____
6. Outlets/overflow spillway	(Annual, After Major Storm)		
Good condition, no need for repair		____	____
No evidence of erosion		____	____
No evidence of any blockages		____	____
7. Integrity of biofilter	(Annual)		
Biofilter has not been blocked or filled inappropriately		____	____

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections ___________
Correct noted facility deficiencies by ______________________

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections.

Site reinspection accomplished on ________________________

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

________________________________ ____________________________________
Signature of Inspector

Chapter 7
Inspection and Maintenance After Construction

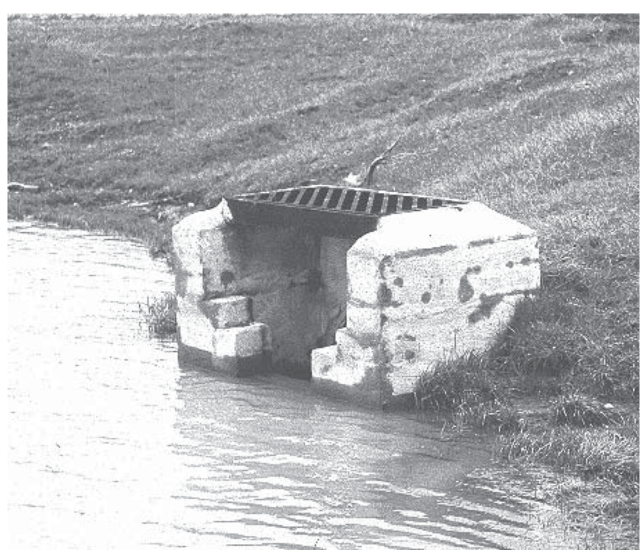
1. OVERVIEW

Once construction is satisfactorily completed, the long term assurance of adequate facility performance begins. Stormwater management systems are expected to perform their stormwater quality and quantity control functions as long as the land use they serve exists. Failure to maintain these systems can create the following adverse impacts:

- increased discharge of pollutants downstream.
- increased risk of flooding downstream.
- increased downstream channel instability, which increases sediment loadings and reduces habitat for aquatic organisms.
- potential loss of life and property, resulting from catastrophic failure of the facility.
- aesthetic or nuisance problems, such as mosquitoes or reduced property value, due to a degraded facility appearance.

All of these adverse impacts can be avoided through proper and timely maintenance of stormwater management facilities. A major concern created by these impacts is the general public's expectations about their quality of life which is provided, in part, by construction of stormwater management systems. Inadequate maintenance means the general public may have a false sense of security. ***If we are not going to adequately address the maintenance issues of stormwater management system implementation, the facilities should not be constructed in the first place.*** The most common cause of stormwater system failure is the lack of adequate and proper operation, maintenance, and management.

As discussed in Chapter 5, the owners of stormwater management systems must be educated to understand the importance of the facility, and their obligations to assure its continued function. A case study illustrates the importance of education in assuring proper OMM. One of the authors conducted a site visit to an extended dry detention system that serves a residential subdivision. The facility has a perennial or dry weather flow through it which it passes through an orifice in the outlet structure. During the winter months, children in the subdivision plugged up the orifices in the outlet structure so water would back up in the pond. This ponding let them ice skate when temperatures allowed. As a result, when spring came water could not discharge properly, water depths increased, and all of the flow was passing through the emergency spillway, which was intended to only



Broken up outlet structure.
Having the grate on top doesn't really provide any factor of safety.

convey infrequent emergency flows. As a result, the emergency spillway eroded and the entire pond embankment failed. This was subsequently repaired at considerable county expense. ***This problem could have been avoided if members of the community had known why that facility was built in their community, and knew the importance of all facility components working properly***.

Good design and construction can reduce subsequent maintenance needs and costs, but they cannot eliminate the need for maintenance altogether. ***Maintenance will always be needed. It will require a long term commitment of time, money, personnel, and equipment by the individuals responsible for operation and maintenance. At the same time, assuring maintenance represents a long term commitment of public agency staff. They are needed to conduct maintenance inspections to ensure that the responsible maintenance entity is adequately performing its responsibilities***.

1.1 Intended Readers

This Chapter is equally important to:

- **Agency maintenance inspectors,**
- **Facility owners, and**
- **Facility maintenance personnel.**

In addition, individuals responsible for facility design and review should be aware of the equipment used for maintenance and normal maintenance activities. This awareness will enable them to select stormwater management system locations and develop designs that will facilitate, rather than hinder, maintenance efforts.

2. HOW MAINTENANCE CAN REDUCE ADVERSE DOWNSTREAM IMPACTS

It will be helpful to further discuss the adverse impacts of maintenance neglect mentioned in the overview. Understanding the impacts caused by inadequate or improper system OMM is very important. While some of these impacts may be obvious, an expanded discussion may lead to a greater understanding by all individuals responsible, in some way, for stormwater system operation, maintenance, and management.

2.1. Increased Discharge of Pollutants Downstream

Stormwater management systems treat stormwater runoff through a number of processes:

- Gravity settling of particulate materials. This is normally achieved by increasing the detention time of water in BMPs, so that the particle settling velocity is greater than the flow velocity of the particle towards the facility outlet.

- Filtering of particulate material by vegetation or media mixtures, such as soil, sand, gravel, compost, or other materials.

- Adsorption of pollutants onto or absorption into organic material.

Any reduction in the volume or area of storage reduces detention time or effective area of flow. This will decrease the ability of the BMP to remove pollutants. For stormwater management facilities that are designed for stormwater treatment only, lack of maintenance may negate any benefits derived from its construction. In these situations, the lack of maintenance means that the original investment of funds for stormwater treatment is, to a large extent, wasted.

2.2. Increased Risk of Downstream Flooding

In addition to water quality reductions, there is an increased risk of flooding downstream if the necessary storage volumes are not available when they are needed. Sediments deposited on the bottom of ponds gradually accumulate and take up volume that is needed during flood events. Many times downstream land use decisions are made with the knowledge that upstream stormwater management systems reduce (or prevent increases in) floodplain elevations downstream. Development may be allowed downstream in areas protected from flooding by the upstream facilities. ***If these facilities are not maintained, a false sense of security exists within the community which could eventually result in significant loss of property and even loss of lives***.

Downstream flooding is directly related to the volume of water traveling through a watershed, together with the time needed for the water to flow through it. With respect to flooding concerns, stormwater management programs generally do not attempt to significantly reduce the total volume of water traveling downstream. Even if infiltration practices are used, they sometimes are sized only for stormwater treatment. They do not have adequate volume available to significantly reduce runoff volumes from larger storms such as the 50 or 100 year event. Instead, stormwater systems modify the time needed for water to travel through a watershed. While the volume is the same, stormwater systems detain runoff, altering the timing of the delivery of water. The end result is that the increased volume of water traveling through the watershed flows for longer periods of time even though the peak discharges are reduced.

2.3 Increased Downstream Channel Instability

Increased downstream channel instability, which increases sediment loadings and reduces habitat for aquatic organisms, may result from a lack of facility maintenance. Stormwater management facilities, depending on the local, regional, or state program, may have channel erosion prevention as a major program goal. In these situations, inadequate stormwater system maintenance may not achieve stated goals or may actually exacerbate channel erosion scour problems. This may occur because of increased stormwater discharges from sediment filled ponds, or increased volumes of stormwater being discharged from clogged infiltration practices.

Increased channel erosion in an urban environment.

With respect to downstream habitat, the scouring of channel boundaries increases channel sedimentation which, in turn, reduces available habitat and smothers bottom dwelling organisms. Beside sediments resulting from channel erosion, improper maintenance of a stormwater management system may result in the release of eroded sediments from the facility itself, or from sediments in upstream contributing drainage areas traveling through the facility and then downstream.

2.4. Potential Loss of Life and Property

Interwoven with the increased risk of flooding and channel instability is the issue of loss of life and property. This can result from a catastrophic occurrence, such as the sudden failure of a pond embankment, or through the creation of a hazardous condition such as steep stream banks or water flowing deeper than expected.

***Safety must be the single most important purpose of a stormwater management system*.** Loss of life associated with OMM of a stormwater management facility could have long term repercussions for the entire program. For example, a drowning in a sediment basin in Anne Arundel County, Maryland in the mid-1980's led to a County requirement that all sediment basins be fenced. The general public should be aware of any dangers associated with stormwater management systems, but they should not be adversely impacted by a poorly functioning facility.

Erosion around the outlet structure of a stormwater management pond.

Loss of property can also occur from stream channel erosion losses or through increased floodplain damage to channel boundaries resulting from inadequate performance of upstream stormwater management systems.

2.5. Aesthetic or Nuisance Problems

Aesthetic problems are generally related to the appearance of a stormwater management system. Landscaping issues such as grass mowing, tree or shrub appearance, and litter control are all aesthetic issues. They generally are not a serious concern with respect to proper functioning of a facility. However, failure to take corrective actions on small problems can eventually create a significant facility performance problem.

Trees in this stormwater detention basin are an indication that aesthetic maintenance has not been accomplished.

One common problem frequently seen around stormwater management ponds is the dumping of grass cuttings along the pond edge. The cuttings can clog outlets or increase nutrient loadings resulting in increased algae blooms. Another important aesthetic maintenance task is the management of aquatic vegetation in wet detention littoral zones or constructed wetlands. Often the vegetation will change over time, sometimes beneficially and sometimes not. The landowner must consider the aesthetics of basin maintenance initially and during the lifespan of the basin.

Mosquitoes, stagnant water, erosion around the shoreline, or vandalism are examples of nuisance problems. Nuisance problems also represent little structural concern and they are not considered a safety issue. However, nuisance problems, together with aesthetic problems, can result in reduced property values due to a degraded facility appearance and reduced quality-of-life for people living or working near the facility.

3. IMPORTANCE OF CHECKLISTS

Checklists are very important to ensure that all system components are functioning as originally constructed. They are important not only during facility inspection, but they also provide a historical record of facility function. Inspection checklists help to ensure a degree of consistency. It can be expected that different individuals will inspect a facility over the years. By providing common important items in an inspection report, continuity is more easily provided. ***Inspection reports should always be provided to the individual responsible for facility maintenance so that they are aware of the status of their facility***.

3.1. Checklists for Inspection

Checklists provide for consistency of site inspection. They help to assure that all relevant facility components are inspected. Any stormwater system will function only as well as its component parts. Each component must be inspected to ensure effective overall OMM and facility performance.

Checklists, when completed and filed with facility information, provide proof that an inspection was done on a routine basis. This documentation is important in case an outside party requests to review the information, or for liability reduction to demonstrate responsible care. The inspection report also identifies any needed maintenance activities and establishes a schedule for their completion. Finally, the inspection report forms the basis for reinspection following maintenance activities to ensure satisfactory completion of the activities in accordance with the initial inspection report.

Examples of sample inspection report forms are included in the Appendices at the end of this chapter. They should be used as a template by individuals or entities responsible for facility maintenance. They should be modified to address additional or modified local criteria for facility components.

3.2. Checklists to Evaluate Stormwater System Function and Performance

When inspections are regularly conducted, checklists can provide a barometer of facility performance and they can help to determine maintenance scheduling and needs. Rates of sedimentation can be determined by comparing data from previous inspection reports. This can assist in scheduling periodic sediment removal. In a stabilized watershed, the rates of accretion should be fairly consistent. If there is a subsequent increase in the rate of sedimentation, then areas contributing stormwater to the facility should be inspected for erosion problems or sediment sources and corrective steps taken. The responsible maintenance entity must realize that elevated sediment loadings into the facility will lead to increased maintenance costs. In stormwater BMPs such as infiltration facilities, increased sedimentation could necessitate costly reconstruction of the entire facility.

Most importantly, OMM budgeting can be more accurately done if regular inspections and completion of inspection reports are done. Larger budget items can be planned for if inspection reports indicate a growing problem. An example is a riser assembly for a stormwater pond developing rust problems. This situation can be watched and minor steps taken to retard deterioration of the riser assembly, but the riser must be replaced eventually. Knowledge of the increasing rate of corrosion allows for funding to be generated over a longer period of time so the impact of replacement can be minimized.

4. HIGHLIGHTED EXPECTED OMM NEEDS AS A FUNCTION OF SYSTEM COMPONENTS

This section of the chapter will focus on the long term operation, maintenance, and management needs of the different types of stormwater management practices. Since each type of practice includes different components and processes, the OMM requirements are best discussed individually. For each type of BMP, information will be presented on several types of stormwater pollutants and the maintenance activities which ultimately will be needed to remove them before their accumulation adversely affects BMP performance. In addition, the sensitivity of a practice to impaired performance resulting from capture of pollutants will be discussed.

To a large extent, the type of stormwater management system will depend on the goals of a specific state/regional/local stormwater program and the problems for which it was implemented. If flooding is a major concern, retention and the various types of detention practices likely will be used. BMP design will then be based on stormwater quantity objectives. If stormwater quality is an important goal, filtration practices, along with retention and detention systems modified to improve pollutant capture, will be more common. In either case, maintenance concerns are best discussed in terms of the type of facility implemented.

With regards to pollutant reduction, most stormwater management systems are designed to remove sediments. There is enough variation in the types of facilities being used to warrant a more detailed discussion by facility type. One point constantly made is that stormwater management program implementation is best done by using a BMP treatment train concept. Infiltration facilities can reduce the total volume of stormwater runoff while other types of facilities would assist in removal of nutrients, toxic materials, metals, and oil and grease. Accordingly, good operation, maintenance, and management of stormwater systems requires awareness of most available types of BMPs since not just one type may be installed on a site.

Individuals need to be aware of the sensitivity that individual BMPs have to reduced performance caused by accumulation of pollutants. It is important to recognize that stormwater systems are not equal in terms of their ability to remove pollutants, the occurrence of storms which could cause structural damage, and their sensitivity to clogging or impaired performance. Implementing pretreatment practices can significantly reduce the potential for impaired facility performance. For facilities impacted by excess sedimentation, the primary concern is sediments resulting from construction activities. Construction of facilities must be done with a sensitivity to their impaired performance, especially if construction related sediments are allowed to enter the facility while it is being built or after construction but before overall site stabilization.

4.1. Detention and Retention Ponds

Ponds are effective at removing a variety of pollutants. For some pollutants, the performance is well documented and can be expected. For other pollutants, removal mechanisms and processes are less well defined and may vary depending on the design, expected pollutant load, and frequency of maintenance. The variation in performance for some pollutants depends, to a large extent, on whether the pollutant is in a particulate or soluble form. Ponds are less effective at removing soluble pollutants than removing particulates. Exceptions to this rule include BMPs such as wet detention systems or constructed wetlands, where longer detention times together with the biological processes associated with aquatic plants, provide significant reduction in soluble pollutants. These differences will be discussed in the sections on individual pollutants.

A. Sediments

Ponds are most effective at removing sediments from the water column. Figure 7-1 shows that ponds remove sediment by slowing water velocity down, thus allowing time for the sediment's downward velocity to remove the sediment from the water column. As a result, ponds need periodic maintenance to remove sediments deposited on the bottom. The use of sediment forebays can reduce the maintenance problems by reducing the frequency that sediments must be removed from the entire pond. However, this requires more frequent maintenance in the forebay areas. **As discussed in Chapter 9, more frequent maintenance can reduce the risk that accumulated sediments may be considered to be a hazardous waste.**

B. Toxic materials and metals

Toxic materials and metals may either become attached to sediments as a result of cation exchange, or they may be in a soluble form. Ponds are very effective at removing these substances when they are attached to sediments, but they are less effective at removing soluble materials. This is especially true for ponds with traditional detention times of 12 to 48 hours. Wet detention systems, with littoral zones planted with aquatic vegetation, along with constructed wetlands can provide greater removal of soluble toxics and metals. Pollutant removal effectiveness increases with residence time, with a minimum residence time of 14 days recommended. Ponds are especially effective at reducing the release of toxic substances that are inadvertently spilled during a commercial or industrial accident. The pond can function as a holding area until cleanup can be accomplished.

To assure that toxics, especially heavy metals, remain sequestered in the pond's bottom sediments, it is essential that the bottom environment remain aerobic (have oxygen) and that the pH remain neutral. Failure to do this will lead to a release of

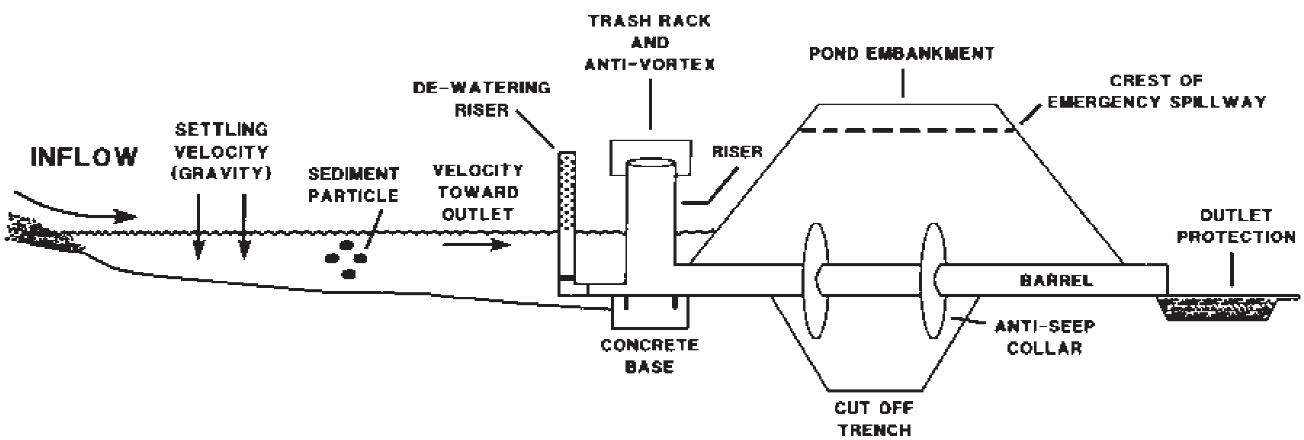


Figure 7-1. Schematic of a pond and the sedimentation process.

the pollutants from the sediments and their reintroduction into the water column.

C. *Nutrients*

Like metals, nutrients, such as nitrogen and phosphorus, in stormwater can be in either particulate or soluble forms. The particulate form of phosphorus can be very effectively removed through adsorption and sedimentation. As with toxics, ponds will only remain effective at removing particulate nutrients if the bottom sediments and water remain aerobic with a pH near 7. If the pond bottom develops an anaerobic (no oxygen) zone or pH rises or falls, phosphorus previously captured can then be converted to a soluble form and reenter the water column.

Most nitrogen forms, on the other hand, are soluble. They are not removed by sedimentation but through the processes which occur during the nitrogen cycle. A key component of the nitrogen cycle is the role of anaerobic bacteria that live on a pond bottom dominated by wetlands vegetation.

If nutrients in general are of concern in program implementation, the treatment train concept is vital. Phosphorus, in particulate form, must be removed via settling and adsorption in a facility maintaining an aerobic environment. Nitrogen could then be removed in a downstream BMP with a two week residence time and anaerobic conditions. Two types of facilities are needed for total nutrient reduction. Biofiltration practices, such as vegetative swales, would be effective at reducing particulate pollutants with the stormwater then entering a constructed wetland for soluble pollutant reduction.

D. *Oils and greases*

Ponds provide for reduction in oils, greases, and other hydrocarbons through volatilization (vaporization). The effectiveness of this process depends on air and water temperatures, winds, and surface turbulence. One seldom mentioned benefit of stormwater management ponds, especially at a commercial or industrial site, is their ability to capture pollutants released during a site spill. For example, a constructed wetland at a Delaware shopping mall received approximately 500 gallons of fuel oil that was spilled on the mall parking lot. The oil entered one of the forebays of the constructed wetland where it was fairly easily cleaned up. Without the pond, the oil would have traveled through the storm drain system and entered receiving waters. This would have created a serious environmental impact and cleanup would have been much more difficult and costly.

On residential sites, oil or automotive fluids may be inappropriately disposed by individual property owners. ***The single most important maintenance recommendation for residential property owners is pollution prevention and pollutant source control in their day to day activities at home***.

E. *The Sensitivity of the Facility to Impaired Performance*

One of the greatest benefits of stormwater management ponds is their resilient performance even when excessive pollutant loadings enter the facility. However, performance will suffer if sediment is introduced in large amounts over a lengthy time frame. Sediments reduce the volume of storage and reduce detention times which ultimately reduce the pond's pollutant reduction effectiveness. This impaired function is not be expected to dramatically occur in a short time frame, but occurs cumulatively over a longer time period if the incoming pollutant loads are consistently elevated.

4.2. Infiltration Facilities

Infiltration facilities, when properly designed and constructed, provide significant pollutant reduction benefits. They also are very effective at reducing the total volume of runoff. By reducing the runoff volume, they reduce downstream channel erosion, reduce the decline in stream baseflow, and reduce pollutant delivery downstream. ***Infiltration practices are sensitive to pollutant clogging of the sides and bottom at the soil/stormwater interface***. Excessive sedimentation can clog these facilities quickly.

A. Sediments

Infiltration practices are effective at reducing the downstream movement of sediments. Removing coarser sediments does not significantly impair their function, but finer grained sediments (below 43 ug) can cause clogging of the facility.

B. Toxic materials and Metals

Infiltration facilities can also be effective at removing toxic materials and metals. ***To minimize the potential that pollutants will move through the soil and into the ground water, infiltration practices should have an organic layer of soil which allows the toxics or metals to attach to the soil particles. Additionally, infiltration practices should be vegetated to help reduce soluble forms of metals. The vegetation's roots also help to maintain the soil's permeability***. Using coarse sandy materials for infiltration will have limited pollutant reduction benefits.

C. Nutrients

Infiltration practices are effective at phosphorus removal as they capture a large percentage of particulate phosphorus and maintain an aerobic environment that keeps the particles attached to the soil in the facility bottom. Nitrogen, on the other hand, can travel through the infiltration system's soils and into the underlying ground water unless the bottom contains organic soils. If nitrogen removal is a program goal, constructed wetlands may be a more appropriate stormwater management practice, especially in areas with coarse sandy soils.

D. Oils and greases

Infiltration facilities may not be effective in areas where significant oil and grease delivery to the facility is expected. Pretreatment of runoff to remove oil and greases should be done before it enters the infiltration system. Significant loadings of oil and greases will cause premature clogging of these facilities and dramatically increase maintenance obligations.

E. The Sensitivity of the Facility to Impaired Performance

Infiltration facilities are very sensitive to impaired performance if excessive amounts of sediments or oils and greases are introduced into the facility. The greatest problem is clogging of soils in the sides and bottom of the infiltration system. This can occur fairly rapidly if inflow pollutant levels are not reduced by pretreatment practices. Other pollutants which are attached to sediments, such as toxic materials, metals, and phosphorus, are not considered a clogging concern. Another problem is poor drainage as a result of high water table, groundwater mounding, or a confining soil layer.

Prolonged wetness encourages microorganism growths that tend to clog the soils.

4.3. Filtration Facilities

Filtration practices have many variations which can enhance their ability to remove a variety of pollutants. Most filters, such as those used in Austin, Texas, Washington, D.C., Florida, and Delaware, use sand as the filter media. To be effective in reducing stormwater pollutants, the sand needs to be fairly fine grained. However, finer grained sands have a slower flow rate than coarser sands creating a careful balancing act in the design of filters. Other filtering materials being developed around the country include compost, activated carbon, and peat. The potential benefits of using these alternative media will not be discussed in this document as they are still somewhat experimental and little is known about their OMM requirements.

Sand filter showing trapped oils and greases.

A. Sediments

Filtration systems are very effective at removing sediments from stormwater. Since most filter designs include some type of detention, sediments are removed from runoff through settling and filtration. Most filter designs require at least 18 inches of sand, which has proven effective in trapping sediments. Another reason at least 18 inches of filter media is recommended is to allow maintenance by scraping an inch or two of sand from the surface of the filter. After several maintenance operations reduce the sand thickness to 12 inches, new sand can be added to restore the thickness to 18 inches. Experience has shown that most pollutants will only penetrate down a few inches into a filter made of fine sands. However, the coarser the sand, the farther pollutants will travel and the more filter media that will need to be removed or replaced when maintenance is finally done.

B. Toxic materials and metals

Toxic materials and metals are removed in filters when they attach to sediments or when they pass through organic materials. This occurs in most sand filters since the surface of the filter becomes very organic as a result of trapping fine sediments and oils and greases. The organic material enhances the ability of the sand filter material to remove toxics and metals. The use of alternative filter media, such as peat, also can enhance the ability of filters in removing toxic materials.

C. Nutrients

Filtration systems only remove particulate nutrients. As such, they can be somewhat effective at removing phosphorus from stormwater. As currently designed, however, they have very little ability to remove nitrogen. Experimental systems and various filter media may improve the nitrogen removal efficiency of sand filters.

D. Oils and greases

Filtration facilities are very effective at removing oil and greases. The Delaware filter was developed primarily for removal of hydrocarbons from small, intensely urban sites, such as gas stations or fast food restaurants. The sedimentation chamber is important in removing hydrocarbons as oil and solids adhere to each other. Oils and greases penetrate only an inch or so into the filter media before being bound up in the sand. However, expectations of performance depend on the gradation of the filter media. Several filter designs recommend C-33 concrete sand as the specified filter media.

E. The Sensitivity of the Facility to Impaired Performance

With respect to maintenance, the question is not if a filter system will clog, but when. Filter systems are very sensitive to excessive loadings of oil and grease which can clog the surface of the filter. The sand filter in Rehoboth Beach, Delaware, provides a good case study. The filter normally requires monthly inspection, with cleanout of the sand surface twice per year. In one instance, an individual dumped waste oil into the facility and immediately caused the sand filter to clog. On one hand, the filter was effective at preventing the downstream migration of waste oil, but this effectiveness caused it to quickly clog.

Sediments can also be a problem for stormwater filters, especially if they are fine grained sediments in the silt/clay category. Coarser sediments do not cause a significant reduction in permeability of the sand and they are generally removed in the sedimentation chamber of the facility.

4.4 Biofiltration Facilities

Biofiltration facilities generally include vegetative filter strips and swales. Physical filtration by vegetation is an important pollutant removal component of biofiltration facilities. Another important filtration mechanism, depending on their character, may be infiltration of stormwater runoff through the surrounding surface and subsurface soils.

A. Sediments

Biofiltration facilities are very effective at removing sediments from stormwater. Their effectiveness is based, to a large extent, on the duration of flow through them. The longer the flow path and residence time, the higher the effectiveness in removing sediments.

B. Toxic materials and metals

There is little information available on the effectiveness of biofiltration facilities in removing organic toxic materials. They are moderately effective (60-75%) at removing metals from stormwater. Removals are fairly low for soluble metals such as zinc or copper.

C. Nutrients

Biofiltration facilities are not very effective at nutrient removal. Phosphorus removal is very modest while nitrogen removal is negligible. A greater level of performance can be expected for nutrient reduction if the biofilter is mowed and the grass cuttings removed from the drainage system. This may not be a realistic expectation as it may rely on numerous individual property owners to do, especially for biofiltration facilities located in residential communities.

D. Oils and greases

Biofiltration practices are effective at oil and grease reduction. They are most effective in removing fairly low levels of oil and grease and can be overwhelmed by excessive loadings.

E. The sensitivity of the facility to impaired performance

Biofiltration facilities are susceptible to impaired performance primarily as a result of excess sediment loadings smothering vegetation. Oils and greases can also be a serious concern as their entry could kill vegetation. These impacts could occur very quickly if large amounts of these pollutants are introduced in a short time frame.

5. INSPECTION FREQUENCY

Suggested inspection frequencies are included in the inspection forms in the Appendices at the end of this chapter. These frequencies should be considered as the maximum interval between inspections. ***It is important to remember that inspections can never be done frequently enough***. More frequent inspections, especially for certain practices such as filters and infiltration practices, should be done whenever possible.

Inspection frequency for stormwater management system maintenance depends on two principal factors:

- local climate and precipitation
- the type of stormwater system

The influence of local climate and precipitation on maintenance frequency will be discussed in the following section, while the influence of practices was discussed in the previous section.

5.1. Local Climate and Precipitation

The frequency of maintenance depends on how much and how often it rains, the potential for large events, and the occurrence of snow and ice. Climate provides one of the foundations upon which stormwater management systems are designed and constructed. ***The recommended time frames for inspection and maintenance will vary depending on local climate and rainfall conditions. It is very important to carefully consider these factors when determining inspection frequencies for a specific stormwater management program.***

A. Local climate

An important local climate consideration is the seasonal aspect of rainfall. A region of the country having a defined wet or dry season will need to consider the maintenance requirements associated with these distinct seasons. This is especially true of practices for which inspections are recommended monthly. During a normal wet season, inspections should be done according to the recommended schedule. However, monthly inspections are probably too frequent during a normal dry season when less frequent inspections will suffice. There is value to conducting inspections more frequently. However, unless they are done voluntarily by an assigned maintenance entity, public inspections will cost money and require staff resources typically unavailable to most stormwater programs. ***Reducing the frequency of inspections during a dry season may be appropriate and allow resources to go farther. However, the appropriateness of less frequent inspections during the dry season ultimately will depend on the type of practices and the drainage area it serves***. The recommended inspection frequencies presented in this Handbook are for those areas which receive rainfall throughout the year.

In addition to the seasonality of rainfall, vegetation growing seasons, especially the dormant seasons, will have an impact on how often a biofiltration or constructed wetland will need to be inspected. The dormant season may provide a good opportunity to inspect a facility for erosion problems due to a winter die back of the vegetation. Areas which could not be inspected during the growing season may be visible when the vegetation dies back.

B. Precipitation

The characteristics of storms, such as rainfall intensity, depth, inter-event time, and percentage of annual precipitation as snow or rain, is also an important factor in determining inspection frequency. Total annual precipitation in the Pacific Northwest is similar to rainfall depths in the mid-Atlantic region, but the nature of rainfall in terms of inter-event dry period, average depth of individual storms, and the seasonal nature of the rainfall is very different. Thus, far different inspection frequencies are merited.

Simply stated, the more rainfall events and the greater the pollutant loading, the more work a stormwater management facility must do. Increased use or loading is directly related to the need for maintenance. ***Inspections may be needed more frequently in areas having a greater number of storms and greater depths per event***.

6. AESTHETIC AND FUNCTIONAL MAINTENANCE

Maintenance can be broken down into a number of different categories, but two primary categories are aesthetic/nuisance maintenance and functional maintenance. These two categories can overlap at times. They are mutually important to each other and each is equally important. ***Functional maintenance is important for performance and safety reasons, while aesthetic maintenance is important primarily for public acceptance of stormwater facilities, and because it may also reduce needed functional maintenance activities*****.**

A well landscaped pond in Newark, Delaware is a centerpiece for the office park.

Both forms of maintenance are needed and both must be combined into an overall stormwater management system maintenance program. Both forms of maintenance are included in the checklists in the Appendices to this chapter.

6.1. Aesthetic Maintenance

Aesthetic maintenance primarily enhances the visual appearance and appeal of a stormwater facility. A stormwater system with a good appearance will allow the facility to more easily become an integral part of a community. Aesthetic maintenance is obviously more important for those facilities that are very visible. Underground stormwater systems do not have the need for aesthetic maintenance that above ground, open air systems have. Generally, aesthetic maintenance is more important at ponds and biofiltration facilities, although it may also be important for certain types of filtration and infiltration facilities, such as Austin's sand filter design or landscape infiltration basins. The following activities can be included in an aesthetic maintenance program:

A. Graffiti removal

The timely removal of graffiti will improve the appearance of a stormwater system. Timely removal will also tend to discourage further graffiti or other acts of vandalism.

B. Grass trimming

Trimming of grass around fences, outlet structures, hiker/biker paths, and structures will provide a more attractive appearance to the general public. As much as possible, the design of stormwater facilities should incorporate natural landscaping elements which require less cutting and/or trimming. However, there often are areas where mowing will be necessary to maintain attractiveness as perceived by the average individual.

C. Control of weeds

In situations where vegetation has been established, undesirable plants can be expected. These undesirable plants can adversely impact the aesthetics of a stormwater facility. This can also apply to wetland stormwater systems and wet detention littoral zones which may be invaded by undesirable aquatic plant species. These undesirable plants can be removed through mechanical or chemical means. If chemicals are used, the chemical should be used as directed and left over chemicals disposed of properly.

D. Miscellaneous details

Careful, meticulous, and frequent attention to performing maintenance tasks such as painting, tree pruning, leaf collection, debris removal, and grass cutting (where intended) will allow a stormwater management system to maintain an attractive appearance and help maintain its functional integrity.

6.2. Functional Maintenance

Functional maintenance is necessary to keep a stormwater management system operational at all times. Functional maintenance has two components:

- Preventive maintenance
- Corrective maintenance

6.2.1. Preventive maintenance

Preventive maintenance is the maintenance which is done on a regular basis as detailed in the checklists contained in the Appendices to this chapter. Preventive maintenance tasks include upkeep of any moving parts, such as outlet drain valves or hinges for grates, or maintenance of locks. Preventive maintenance can also include maintenance of vegetative cover to prevent erosion. Examples of preventive maintenance include:

A. Grass mowing

Actual mowing requirements at a facility should be tailored to the specific site conditions, grass type, and seasonal variation in climate. Local soil conservation districts or cooperative extension service offices can provide assistance in determining maintenance requirements for various types of vegetation.

Routine mowing of a detention facility.

B. Grass maintenance

Grass areas require limited periodic fertilizing, de-thatching, and soil conditioning in order to maintain healthy growth. Provisions may have to be made to reseed and reestablish grass cover in areas damaged by sediment accumulation, stormwater flow, or other causes.

C. Vegetative cover

Trees, shrubs, and other ground cover require periodic maintenance, including fertilizing, pruning, and pest control.

D. Trash and debris

A regularly scheduled program of debris and trash removal will reduce the potential for outlet structures, trash racks, and other facility components from becoming clogged and inoperable during storm events. In addition, removal of trash and debris will prevent possible damage to vegetated areas and eliminate potential mosquito breeding habitats. Disposal of debris and trash must comply with all local, county, state, and federal waste control programs. Only suitable disposal and recycling sites should be used.

Example of clogged inlet causing erosion when water overflowed onto vegetated areas adjacent to a stormwater pond.

E. Sediment removal and disposal

Accumulated sediments should be removed before it threatens the operation or storage volume of a stormwater management system. Disposal of sediments is discussed in Chapter 9 and must comply with local, county, state, or federal requirements. Only suitable disposal areas should be used. Sediment removal in infiltration systems must also include monitoring the porosity of the subbase, replacing or cleaning the pervious materials as necessary, and reestablishing vegetation.

F. Mechanical components

Valves, sluice gates, pumps, fence gates, locks, and access hatches should remain functional at all times. Regularly scheduled maintenance should be performed in accordance with the manufacturers' recommendations. All mechanical components should be operated during each maintenance inspection to assure continued performance.

G. Elimination of mosquito breeding habitats

The most effective mosquito control program is one which eliminates potential breeding habitats, or, in the case of open

Potential mosquito habitat resulting from inadequate drainage.

water ponds or wetlands, ensures that optimal conditions are maintained for the survival of mosquito control organisms. ***Any stagnant pool of water can become a mosquito breeding area within a matter of days***. Ponded water in open cans, tires, and areas of sediment accumulations or ground settlement can become mosquito breeding areas. Local mosquito control programs can be contacted for assistance and advise on minimizing mosquito problems.

H. Facility maintenance

A maintenance program for monitoring the overall performance of the stormwater management system should be established. Wet detention and wetland systems, are especially, complex environments. They require a healthy aquatic ecosystem to provide maximum benefits and to minimize needed maintenance. It is important to remember that potentially large problems can be avoided if preventive maintenance is done in a timely fashion.

6.2.2. Corrective maintenance

Corrective maintenance is required on an emergency or non-routine basis to correct problems and to restore the intended operation and safe function of the stormwater management system. Corrective maintenance is not done on a scheduled basis but on an as needed basis. Failure to promptly address a corrective maintenance problem may jeopardize the performance and integrity of the facility. It may also present a potential safety problem to those living adjacent to or downstream of the facility. Corrective maintenance activities include:.

Rermoval of debris from the entrance of an outlet structure in a detention facility.

Sediment cleanout of a stormwater management pond.

A. Removal of debris and sediment

Sediment, debris, and trash which threaten the ability of the facility to store or convey water should be removed immediately and properly disposed of to restore proper functioning of the facility. A blocked inlet or outlet means that stormwater will travel in an area that was not normally designed as a flow path. In the case of an inlet, the stormwater could travel over a curb onto a grassed area and scour that area. If the outlet is blocked, water will back up in the facility and may travel through the emergency spillway or overflow area. These areas are not designed for frequent flow and may become eroded. If sediments are clogging a facility component, the lack of an available disposal site should not delay removal of the sediments. Temporary arrangements should be made for handling the sediments until a more permanent arrangement is made.

B. Structural repairs

Repairs to any structural component of the facility should be made promptly. Equipment, materials, and personnel must be readily available to perform repairs on short notice. The immediate nature of the repairs depends on the type of damage and its effects on the safety and operation of the system. Where structural damage has occurred, the design and conduct of repairs should be undertaken only be qualified personnel.

C. Dam, embankment and slope repairs

Damage to dams, embankments, and slopes must be repaired quickly. Typical problems include settlement, scouring, cracking, sloughing, seepage, and rutting. A concern in an embankment with a barrel assembly or outflow pipe through it is seepage around the outside of the barrel. This can also cause movement of embankment soils, which can weaken the embankment. Repairs need to be made promptly. Other temporary activities may be needed, such as drawing down the water level in the facility to relieve pressure on a dam or embankment, or to facilitate repairs. Crack repair in a concrete structure may necessitate draining the facility and cleaning the area of the crack prior to repair. If the facility is to be dewatered, pumps may be necessary if there is no drain valve.

D. Elimination of mosquito breeding areas

If neglected, a stormwater system can become a mosquito breeding area, especially facilities which are designed to drain and dry out, but which do not. Corrective action may be needed if a mosquito problem exists and the stormwater facility is the source of the problem. Local mosquito control experts should be consulted for advice. If mosquito control in a facility becomes necessary, the preventive maintenance program for mosquitoes should be reevaluated, and more emphasis placed on control of mosquito breeding habitats.

E. Erosion repair

Vegetative cover is necessary to prevent soil loss, maintain the structural integrity of the facility, and maintain it's pollutant removal benefits. Where a reseeding program has been ineffective, or where other factors have created erosive conditions (i.e., pedestrian traffic, concentrated flow, etc.), corrective steps should be taken to prevent further loss of soil and any subsequent danger to the performance of the facility. There are a number of ways that corrective action can be taken. These include erosion control blankets, riprap, sodding, or reduced flow through the area. Local experts should be consulted to address erosion problems if the solution is not evident.

F. Fence repair

Fences can be damaged by any number of factors, including vandalism and storm events. Timely repair will maintain the security of the site.

G. Elimination of trees, woody vegetation and animal burrows

Woody vegetation or animal burrows can present problems for dams or embankments. The root system of woody vegetation can undermine dam or embankment strength. If the vegetation dies and the root system decomposes, voids can be created in the dam or embankment which weaken the structure. Preventive maintenance can avoid this problem. However, when it occurs through lack of a preventive maintenance program, steps must be taken to eliminate the problem. Vegetation, including root systems, must be removed from dams or embankments and the excavated materials replaced with proper material at a specified compaction (normally 95% of the soils maximum density). Animal burrows should be filled and steps taken to remove the animals if burrowing problems continue to occur. In an urban environment, animals of concern are usually muskrats or beavers. If the problem persists, local wildlife officials should be consulted regarding removal steps. This consulting is necessary as the threat of rabies in some areas may necessitate the animals being destroyed rather than relocated.

H. Snow and ice removal

Accumulations of snow and ice can threaten the functioning of a stormwater management system, particularly at inlets, outlets, and overflow emergency spillways. Providing equipment, materials, and personnel to monitor and remove snow and ice from these critical areas is necessary to assure the continued functioning of the facility during the winter months.

I. General facility maintenance

In addition to the above elements of corrective maintenance, general corrective maintenance should address the overall facility and it's associated components. If algae growth becomes a problem for ponds, or if an infiltration facility does not totally drain, steps must be taken to reestablish the original performance of the system. ***Stormwater facilities often are very complex systems. They will work only as long as each individual element functions correctly. If corrective maintenance is being done to one facility component, other components should be inspected to see if maintenance is needed. There may be a cost savings in conducting numerous maintenance activities if equipment is on site which could improve a number of needed maintenance items.***

What individual would have three different keys to open the gate to enter a facility?

7. TRAINING NEEDS, INCLUDING AN INSPECTOR TRAINING AND CERTIFICATION PROGRAM

There are going to be many individuals who are involved in stormwater management system maintenance activities. Having individuals conduct these activities, including inspection, without training reduces the potential for proper facility inspection and maintenance.

It is important that educational programs be developed and implemented to ensure long term performance and function of stormwater management facilities.

7.1. Mandatory Versus Voluntary Educational Programs

It is recommended that an inspector's training program be mandatory. An inspector must know what components of a stormwater management facility are integral to proper function and safety. This recommendation is consistent with that made in Chapter 4.

A training program for owners and operators of stormwater facilities is best done on a voluntary basis where the appropriate regulatory agency provides educational materials and programs for facility owners and operators. In addition to these materials and programs, annual interaction is important. When public agency inspections are done on stormwater systems, the owner and/or operator should also be present. This interaction can provide owners and operators with a greater understanding of various facility components and their importance to overall facility function.

The inspection agency should also contact all facility owners and operators and offer to conduct an inspection with them at the convenience of the owner or operator. This may represent somewhat of a hardship on the inspection agency, especially for residentially-owned facilities, since inspections may be necessary after normal work hours or on weekends. ***It is vital to make owners and operators aware of their obligations and responsibilities for their stormwater systems. Meetings on site are necessary to instill that recognition.***

7.2. Components of an Inspector Training Program

A required inspector training program must be structured, have classroom or lecture sessions that must be attended, and a program manual that is kept by those taking the course. The course curriculum should include much of the material in this Handbook and should include the following components:

1. Institutional background for the stormwater management program.
2. Discussions of why stormwater facilities are important for stormwater quantity and quality control.
3. Basic soils and geology information.
4. Basic hydrology and hydraulics so inspectors have an understanding of the processes involved in rainfall and runoff).
5. Explanation of the specific legal authority and regulatory requirements of the stormwater management program. This should detail the inspection requirements and penalty options.
6. Discussion of the different types of stormwater management facilities being used in a given jurisdiction. This discussion will include the treatment processes of the individual facilities and the maintenance issues associated with each type of facility.
7. The impacts of maintenance on water quality, including disposal of waste material.
8. How to read plans and understand specifications.
9. How to inspect a stormwater management facility. This will include use of the maintenance inspection checklists similar to those presented in the appendices at the end of this Chapter.
10. Enforcement options including available inspection and enforcement report forms.
11. Case studies showing construction and

maintenance of stormwater management facilities. The case studies should include construction techniques and sequences so the inspectors would understand the importance of components that are not normally visible.

12. Issues related to actual maintenance of stormwater management facilities. This would include disposal of materials removed from the facility and any concerns regarding the hazardous nature of removed sediments.

7.3 Components of an Operators Training Program

For the most part, individuals responsible for maintenance of stormwater management systems seldom have that job as their primary responsibility. For example, this may include the officers of a residential property owners associations, or staff charged with overall property maintenance at commercial or industrial sites. ***These individuals need basic education about stormwater management systems, their operation, and maintenance. They do not need to know about more "abstract" topics such as institutional backgrounds, etc.*** That information should be available upon request, but isn't important during a workshop or training session where they are giving up their own time to attend.

An operator's training program will have many of the same components as the inspector's training program but with less emphasis in some areas. The training program should focus instead on practical aspects of stormwater facility operation, maintenance, and management. The focus should be on matters which are directly applicable to OMM situations. The operators program should consist of a stormwater system operator's manual, in conjunction with classroom or lecture sessions where the individual course topics can be added or removed depending on the audience. The manual would be more comprehensive than the training course, and would provide information that is not necessary in a training course but which could be beneficial depending on an individual's interest. The course could consist of the following components:

1. Discussions of why stormwater facilities are important for stormwater quantity and quality control.
2. Specific legal authority and regulatory requirements for the maintenance of stormwater management systems. This would clearly state the obligations associated with facility ownership.
3. Discussion of the different types of stormwater management facilities which are being used in a given jurisdiction. This discussion will include the treatment processes of the individual facilities and the maintenance issues associated with each type of facility. It should include a series of modules for each type of facility which would be provided in a specific discussion.
4. The impacts of maintenance on water quality, including disposal of waste material.
5. How to read the plans and understand appropriate specifications.
6. How to inspect a stormwater management facility. This includes the use of maintenance inspection checklists similar to those in this chapter's appendices. This would also consist of topics or presentations for individual types of facilities which could be presented depending on the BMPs of particular interest to the attendees.
7. Issues related to actual maintenance of stormwater facilities. This would include disposal of materials removed from the facility and any concerns regarding the hazardous nature of removed sediments.

8. EQUIPMENT AND RESOURCES NEEDED

Inspector equipment needs are discussed in Chapter 6 and they are again provided and expanded on here for inspectors who may be responsible for stormwater management facility maintenance only. Essential equipment for an inspector includes:

- A locke level or other surveying equipment.
- Flashlight
- Crowbar
- Tape measure and other measuring device (survey rod), such as a clear PVC tube, to determine sediment accumulation depths in facilities.
- Local erosion and sediment control or stormwater management handbooks.
- Rain and foul weather gear.
- Copies of necessary inspection reports and forms.
- Business cards or other means of identification.
- A camera to document field conditions in case an enforcement action becomes necessary.

Insufficient staff is a chronic problem for most stormwater system inspection and maintenance programs. ***Since most public agencies will never have enough inspectors, the issue of public versus private inspectors to conduct annual maintenance inspections should be considered. Regardless of the program structure, some individual must be responsible for conducting maintenance inspections or assuring that some qualified entity or person is performing inspections*.** The public entity responsible for ensuring maintenance of stormwater facilities must have resources available to conduct periodic inspections to ensure facility performance.

Maintenance inspections, like construction inspections, offer an opportunity to use private inspectors who have attended and passed the inspector certification course. As part of the permit approval process, a stormwater system approval should require the land owner or developer to establish a legal maintenance infrastructure. This could include requiring the permittee to retain the services of a certified private inspector to conduct annual inspections of completed stormwater systems. Copies of the inspection reports would be transmitted to the public agency responsible for maintenance and the property owner or stormwater system operator. This approach may reduce the necessity for public agency inspection. However, public inspectors will still be needed to periodically ensure the accuracy of the private inspector's reports and to initiate necessary enforcement action.

***Another key requirement of all stormwater management programs is requiring operators to have the financial capability to ensure that they meet their facility maintenance obligations*.** The agreements provided at the end of Chapter 4 contain legal authority to conduct needed maintenance in the event of default by the responsible private entity. Chapter 8 provides cost information for many maintenance tasks. Stormwater system owners or operators must be made aware of these costs, how often they can be expected to be incurred, and have a mechanism to collect money to accomplish the maintenance. These can be in the form of monthly or annual assessments within a community, or the ability to assess individual owners when the need arises.

9. TYPICAL OMM TOOLS

There are a number of tools which are used in the maintenance of stormwater management systems. These are discussed to assist inspectors and facility owners in developing specific facility maintenance programs. Actual equipment and material requirements should be determined on an individual basis for each facility. The information presented here is adapted from the "Stormwater Management Facilities Maintenance Manual" (NJDEP, 1989).

Grass maintenance equipment

1. Tractor-mounted lawn mowers
2. Riding lawn mowers
3. Hand mowers
4. Gas powered trimmers
5. Gas powered edgers
6. Seed spreaders
7. Fertilizer spreaders
8. De-thatching equipment
9. Pesticide and herbicide application equipment
10. Grass clipping and leaf collection equipment

Vegetative cover maintenance equipment

1. Saws
2. Pruning shears
3. Hedge trimmers
4. Wood chippers

Transportation equipment

1. Trucks for transportation of materials
2. Trucks for transportation of equipment
3. Vehicles for transportation of personnel

Debris, trash, and sediment removal equipment

1. Loader
2. Backhoe
3. Grader
4. Dragline
5. Vacuum equipment

Miscellaneous equipment

1. Shovels
2. Rakes
3. Picks
4. Wheel barrows
5. Fence repair tools
6. Painting equipment
7. Gloves
8. Standard mechanics tools
9. Tools for maintenance of maintenance equipment
10. Office space
11. Office equipment
12. Telephone
13. Safety equipment
14. Tools for concrete work (mixers, form materials, etc.)

Inspector equipment during a routine maintenance inspection

1. Flashlight
2. Locke level or survey equipment
3. Approved facility plans
4. Measuring rod (to determine depth of sediment accumulation)
5. Crowbar (removal of cast iron covers)
5. Inspection report form
6. Pen or pencil

Inspector equipment (when on site during the maintenance of a stormwater facility)

1. Gloves
2. Safety hat
3. Safety glasses
4. Safety boots
5. Inspection report form
6. Pen or pencil
7. Lock level or survey equipment
8. Approved facility plans

Materials

1. Topsoil
2. Fill material
3. Seed
4. Soil amendments (fertilizer, lime, etc.)
5. Chemicals (pesticides, herbicides, etc.)

6. Mulch
7. Paint
8. Paint removers (for graffiti)
9. Spare parts for equipment
10. Oil and grease for equipment and stormwater management facility maintenance of mechanical components
11. Concrete

10. IMPORTANCE OF TRACKING OPERATION, MAINTENANCE, AND MANAGEMENT

Facility tracking and recording are important components of stormwater facility maintenance programs. In this day and age, there is no reason why maintenance cannot be tracked using computerized data bases. This would allow inspectors to be assigned an inventory of facilities to inspect and provide easily accessible information on when OMM was done last and when the next inspection may be needed. The data entered into the computer tracking system could include identification numbers for each facility, facility type, facility locations, special maintenance needs, and data from previous inspections. At the conclusion of each site visit, the inspector enters a maintenance needs assessment into the computer data base. The computer could then generate a maintenance work order.

This approach would help to ensure that problems are corrected in the order of the risk that they pose. This type of system would also ensure that no facilities "fall through the cracks" in terms of annual inspections and maintenance. ***Tracking of when a facility was last inspected and the facility's status should never rely on the memory of individual inspector***.

11. PRIORITIZING MAINTENANCE TASKS

In terms of prioritizing maintenance, corrective maintenance is a high priority whenever it is needed. Preventive maintenance is next, followed by aesthetic maintenance. All of these forms of maintenance are needed, but **prioritizing is necessary, especially when there is a safety or potential safety concern, or when there is limited staff and/or equipment.**

The items previously considered as corrective maintenance include, in order of priority from most important to least important:

- Structural repairs
- Dam, embankment and slope repairs
- Erosion repair
- Removal of debris and sediment
- Elimination of mosquito breeding areas
- Elimination of trees, woody vegetation, and animal burrows
- General facility maintenance
- Fence repair
- Snow and ice removal

Preventive maintenance importance and priority depends to a large extent on the type of BMP. Biofiltration facilities perform only if mowing is routinely accomplished, yet wet ponds may only need mowing on an annual basis. As such, prioritizing is not as important as ensuring that preventive maintenance is accomplished. Preventive maintenance, as discussed earlier, includes:
:

- Grass mowing
- Grass maintenance
- Vegetative cover
- Trash and debris
- Sediment removal and disposal
- Mechanical components
- Elimination of mosquito breeding habitats
- Other specific facility maintenance items

The City of Bellevue, Washington has developed a stormwater facility maintenance

TABLE 7-1. BELLEVUE (WA) STORM FACILITY MAINTENANCE PRIORITIZATION SYSTEM		
Priority	**Criteria**	**Example**
A	Hazard to life or health - a situation presenting substantial likelihood of injury.	Partial collapse of an occupied structure creates roadway hazard which has a reasonable likelihood of causing a traffic accident; hazardous working conditions for utility crews
B	Hazard to structures - a situation presenting a reasonable liklihood of damage to structures.	Damage to buildings, roadways,utilities, etc.
C	Hazard to property - a situation presenting a reasonable likelihood of property damage	Erosion; landscape damage; sedimentation
D	Nuisance	Inconvenient situation for maintenance crews, small amounts of standing water.

prioritizing system, which is shown in Table 7-1.

12. SAFETY ISSUES DURING MAINTENANCE INSPECTIONS AND DURING ACTUAL MAINTENANCE

The importance of inspector and maintenance personnel safety when conducting maintenance inspections and activities cannot be overemphasized. Individual safety must be a paramount consideration when conducting maintenance inspections or performing maintenance.

12.1 Safety Issues During Maintenance Inspections

Safety issues during maintenance inspections are, for the most part, common sense items which should be considered in any outdoor activity. Possible concerns or issues include:

- Look out for holes. A hole can be very small in circumference but deep. In the vicinity of a stormwater management facility a hole can be an indication of a serious problem. When conducting a

Example of a hole on a stormwater pond embankment. This indicates two concerns: (1) watch where you walk; and (2) the pond has serious problems with piping around the barrel assembly. If you see this, get assistance.

maintenance inspection, ***look where you walk***.

- Animals can present a serious concern. Rabies is a concern with wildlife and animal bites which could have severe consequences. Be careful around geese. Geese are very territorial, and can be extremely aggressive. Look out for snakes.

- Be careful lifting manhole covers or other structural covers in stormwater facilities. These items can be very heavy, can slip, and cause serious injury, such as the loss of a finger. In addition, since they are heavy, back problems can occur if covers are lifted alone or incorrectly.

Inspectors lifting a manhole cover of a Washington, DC sand filter. Care must be taken in cover removal and replacement.

- Poison ivy, poison oak, or other plants can present a problem depending on the individual's allergic reaction to them. This can also present a problem during maintenance when vines from cutting woody vegetation may lie all over a site.

- Never enter a confined space unless you have been trained and have proper safety equipment in accordance with OSHA Regulations. Do not enter pipes or conduits unless another individual is present during the inspection. Do not enter a pipe or conduit, even with others present, if there is any concern regarding the structural strength of the pipe or conduit.

- Be careful not to walk in water when the depth is unknown or where there may be steep slopes below the water line.

- Be careful of nails, broken glass, or other sharp objects. Soft bottom shoes, such as athletic shoes, may be more comfortable for general wear, but they are not as safe as hard soled shoes. Fences can tear clothing or cause cuts, which may necessitate medical treatment.

- Gloves should be worn if any mechanical parts or structural components are going to be handled. This should be done for safety reasons (cuts, abrasions, etc.) and for health reasons, especially where pollutants or other materials can coat the hands then get rubbed into eyes or the mouth. Always wash hands after an inspection where items are manipulated, especially if gloves are not worn.

- In systems which are somewhat sealed with poor ventilation, be careful with cigarettes, lighters, or other open flames. Also be sure to allow a facility to vent for a period of time if a peculiar odor is present. Do not enter any confined space unless the atmosphere has been checked and proper safety equipment is worn and/or erected.

12.2. Safety Issues During Maintenance Activities

During maintenance activities, the typical concerns exist around any construction equipment. ***Remember, you can see equipment while they are operating, but equipment operators may not see you.***

- Equipment should always be operated safely and in accordance with manufacturers specifications.
- Call utility companies before initiating any maintenance activity involving any excavation. Look for overhead wires before operating any equipment which could touch the wires.
- Before starting any maintenance activity, be sure that all necessary equipment or replacement parts are onsite or are readily available. In the case of sediment removal, have the disposal location staked out or identified.
- Excavated areas that cannot be filled at the end of a work day should be covered, when possible, or clearly identified and marked off.
- When working in a residential community, the residents should be educated about the maintenance activity and how long it will take.
- Don't cut corners when doing maintenance activities. Be careful. Always be aware of what is around you. Take the time needed to do the job right. Recognize that things go wrong, and taking time to do quality work will save time and money in the long run.
- Wear a hard hat, steel toed shoes, safety glasses, ear plugs, etc. if in an area where construction equipment (or operating equipment) is operating.
- Mowing can be hazardous so be careful around mowers that are running. Take special care when mowing steep slopes. Be sure to wear safety glasses, steel toed shoes, and ear plugs while mowing.
- Gloves should be worn if any mechanical parts or structural components are going to be handled. As stated before, this needs to be done for both safety and health reasons. Always wash hands after an inspection where items are manipulated, especially if gloves are not worn.

13. SPECIFIC MAINTENANCE ACTIVITIES FOR EACH TYPE OF FACILITY

Specific BMP design criteria varies from jurisdiction to jurisdiction, so the frequency of maintenance for the range of BMPs will vary also. An example of this variation in criteria may be the design of sediment forebays in ponds, or the requirement for pretreatment practices. This section will provide information that is generally applicable to the individual types of facilities. However, it cannot be too specific regarding time frames since they are influenced by local criteria. Recommended frequency of inspections is provided in the checklists in the chapter's appendices.

This section will also present specific examples of maintenance problems associated with individual practices. It is extensively illustrated to clearly show examples of functional maintenance problems that may occur at different types of BMPs. Some general recommendations on the frequency of maintenance activities will be provided. ***However, maintenance needs are so specific to the land being served by the stormwater facility and the pollutant load being delivered***

to the facility, that actual conditions will vary from site to site. Actual maintenance frequency should depend on the results of routine inspections which can determine the rate of accumulation of materials in the individual facility.

The discussion will be broken down into the four main classes of stormwater practices:

- Detention and retention ponds, including wetlands
- Infiltration facilities
- Filtration facilities
- Biofiltration facilities

Example of a dry detention facility showing the degree of mowing required and the riprap pilot channel.

13.1 Detention and Retention Ponds

Maintenance activities for detention and retention ponds have many similarities, but there also are some differences in the types of maintenance that are needed. Dry detention systems have more lawn areas that must be mowed. Mowing of dry detention facilities should be done at least once per year to prevent the growth of woody vegetation on the embankment. Monthly or more frequent mowing is necessary if good turf grass cover is expected or desired.

In addition, dry detention systems frequently have pilot or low flow channels to convey smaller flows. These pilot channels may become undermined, if made of concrete, or if made of stone, may become choked with vegetation and require chemical treatment to re-establish flow conveyance ability. Maintenance efforts for pilot channels will be done on an "as needed" basis. Careful inspection should be done on concrete pilot channels, as their undermining will jeopardize the structural integrity of the pilot channel.

Wet detention systems with their normal water pool are effective at converting inorganic nitrogen to organic nitrogen. Consequently,

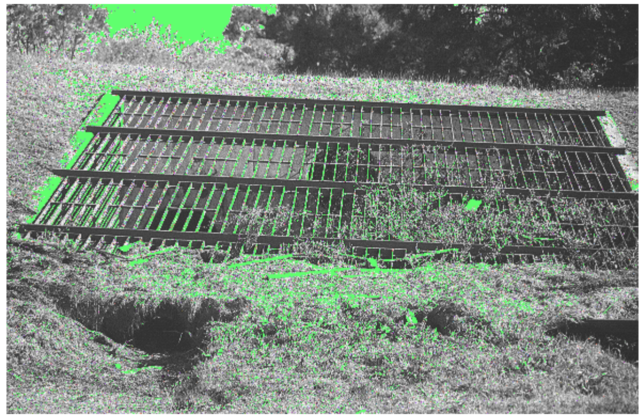
Example of trees all around the detention facility perimeter. It is obvious that maintenance has not been done in years.

A constructed wetland without sediment forebays filling in. This facility is about 10 years old and will need to be dredged of sediments within the next 10 years. Constructed wetlands are very susceptible to filling in if inflow sediments are significant.

Example of a forebay prior to flow entering the wet pond, which is located in the rear of the picture.

this may create algae problems unless littoral zones are planted with aquatic vegetation. Wet detention systems also more commonly have forebays to remove heavier sediments. As such, forebay maintenance is an important issue for wet detention systems which must be considered. Frequency of forebay maintenance depends on the incoming pollutant load and the forebay size.

Extended detention facility where water quality is provided by the small orifice at the bottom of the weir. Maintenance should be mainly concerned with keeping the grate unclogged.



Example of debris which is beginning to clog the outlet structure of a detention facility.

Both dry and wet detention systems have the potential for debris clogging an inlet or outlet structure. There can be a surprising amount of debris generated in residential communities, and commercial facilities can expect debris of all sorts. Inspections for debris should be made on a monthly basis or after rain events to ensure that all components of the stormwater facility are operating as required.

Removal of sediments will also be needed on a periodic basis. Coarser sediments can be expected to be found close to the pond inlet, with finer sediments expected to be deposited closer to the pond outfall. In terms of volume, the coarser sediments will occupy a greater volume and maintenance removal of these sediments will be needed more frequently than removal of finer sediments. **Studies of detention ponds used by the Florida Department of Transportation indicate that sediments need to be removed about once every 10 to 20 years.** Using forebays, which can be more easily cleaned out more frequently, can increase the time before sediments will need to be removed from the entire pond. Recommendations for disposal of collected sediments are presented in Chapter 9.

Pond inflow point clearly showing the coarser sediments dropping out of suspension .

Erosion behind the grouted riprap wingwall will eventually cause failure of the riprap, which will increase sediment loadings downstream negating the BMP's benefit.

Removing sediment from a wet pond should be done by draining the water down to the lowest possible elevation. If possible, a small pool of water should be left to provide habitat for the resident fish population. Removing sediment while having a normal pool of water will cause significant turbidity with the finer sediments traveling downstream. When the sediments are removed from the pond, they should be placed at a location where they can dry prior to final placement. It is important to have sediment control provisions included in the maintenance costs to prevent downstream increases in pollutant loadings or to prevent removed sediments from reentering the facility. Sediment removal from dry detention systems is more straightforward. Since these facilities are normally dry, sediments can be removed by an appropriate means and disposed of properly. ***Experience has shown that it is easier and more effective to remove sediments when they are dry and cracked, and thereby separated from the vegetation***. Sediment control during maintenance is still necessary in case of storms that could mobilize stockpiled materials or erode exposed soils.

Erosion problems can occur with either dry or wet detention systems. For the most part they start as small problems which, if uncorrected, can grow into large problems and possibly threaten the integrity of the detention facility. Inspections to locate erosion problems should be done at least annually or after major storms. Evidence of significant foot or bike traffic in areas where vegetation has died indicate potential erosion areas in the future. These areas should be protected from traffic

Gate valve for a stormwater management pond. When maintenance inspections are done, the valve should be operated and lubricated to ensure proper function.

Leakage around the barrel and riser assembly. This could cause piping of water adjacent to the barrel which would jeopardize the structural strength of the facility.

This may be as bad as it gets. This retention facility was in a state of failure. The embankment had to be breached and completely rebuilt. The problem resulted from seepage around the barrel causing embankment soil to move with the flow of water. This failure resulted from poor construction.

or provided with a more erosive resistant ground cover.

Periodic maintenance of structural components must be done to ensure their continued operation. This includes inspecting any joints for possible leakage or seepage. Areas should also be checked for corrosion, valves should be manipulated and lubricated when needed, and all moving parts inspected for wear and tear.

The most important concern of stormwater management detention and retention ponds

Water piping around a barrel. The water is flowing with considerable velocity.

is safety. Situations may occur which, if no action is taken, may cause imminent structural failure of the facility. Inspections must be made at least annually to ensure the safety of a facility. If there is any concern that the facility is unsafe, assistance must be requested from an individual who has expertise in dam safety. ***Failure to take action, when confronted with a potential problem, can increase liability if a failure occurs.*** Complete failures of stormwater management systems generally do not occur overnight. They start as small problems and increase gradually.

Ponds are rather unique when compared to other types of stormwater systems. If filtration, biofiltration, or infiltration facilities fail or clog, their reduced performance generally will not result in downstream safety concerns. Ponds provide effective water quality performance, but that performance is gained at the cost of increased safety concerns. They must be designed correctly, built satisfactorily, and actively maintained. A failure in any one of the three aspects of detention or retention facilities could result in significant problems. Ponds are a valuable tool in controlling stormwater runoff, but care must be taken to ensure that the service they were constructed to provide continues.

Close up sediments clogging an infiltration basin. Silt and clay sediments are the greatest concern since they can seal the basin/soil interface area.

13.2 Infiltration Practices

Infiltration facilities encompass a wide range of BMPs as previously discussed. Maintenance issues are generally related to one or two major concerns:

- clogging
- standing water

Clogging of these practices can occur from sediments entering the facility and sealing the soil surface, preventing infiltration of runoff. Clogging can also occur from excess oils and greases entering the facility, or from microorganism growth which results when water stands too long in the facility. As water infiltrates into the soil, the algae can clog the soil surface and prevent infiltration. Whatever the reason, clogging will cause failure of infiltration practices creating long term problems.

Infiltration facilities must go dry between storm events to provide maximum stormwater management benefits. Their clogging means less runoff is infiltrated and more goes into the overflow system on a more frequent basis. Clogging may also mean that water is permanently present in the facility, which can then become a mosquito breeding area.

Excessive silt-clay sediments have clogged the basin floor causing this infiltration basin to fail.

Algae on an infiltration basin floor has caused failure of the facility by preventing infiltration of stormwater.

Standing water results from clogging which obstructs the flow of water into the ground. Standing water can also result from seasonal high water tables or ground water mounding in the vicinity of the facility. If either of these problems occur, the facility's performance will depend on exfiltration out of the sides instead of the bottom.

Infiltration basin constructed in the water table. Excellent exfiltration out of the basin sides maintaind proper functioning.

If ground water problems persist at the facility, contingency plans may be needed. These could include conversion of the infiltration system to a practice which includes a permanent pool of water such as a wet detention or constructed wetland system. Another alternative is to provide the facility with a structural outlet to prevent seasonal or permanent water pooling. If either of these options are necessary, the appropriate inspection and/or approval agency should be contacted to ensure approval of the modifications. In such cases, future inspections will be based on the modifications rather than maintaining expectations associated with the originally approved and constructed facility.

With respect to maintenance activities, the first step is to inspect the infiltration facility to determine if there is standing water during a period of time when it hasn't rained. ***If standing water exists, then it needs to be determined whether the cause is clogging of the facility, seasonal water table conditions, or ground water mounding*.** This analysis is crucial for determining the next steps. If the problem is caused by a high water table or mounding, an entire new strategy will be needed to correct the problem. If clogging is the reason, maintenance activities will need to be performed to restore desired infiltration rates.

Example of a failed infiltration basin caused by clogging and not seasonal or mounded water table. The basin should be pumped of water and allowed to dry out before sediment is removed.

Ideally, the inspection will find only partial clogging, allowing sediments to be removed when the facility dries out. If the facility is totally clogged, correction is much more difficult. The facility should be drained and allowed to dry out before removing sediments. If sediment removal is attempted while water is standing in the facility, the finer sediments will become suspended and not be removed from the facility. These suspended sediments are responsible for the initial clogging of the practice, and their resuspension will last only until quiescent conditions allow for resettlement.

The facility will never achieve the desired re-establishment of infiltration rates.

Safeguards should be installed during construction to reduce maintenance concerns. However, even with design and construction being sensitive to future maintenance, maintenance problems will occur as they do for all stormwater management facilities. For example, to facilitate maintenance, rock filled infiltration trenches should be designed to have filter fabric placed approximately one foot below the surface of the facility. This fabric is a design point of failure which allows the underlying stone to remain clean. If standing water persists on the surface of the facility, the top foot of stone should be removed and the filter fabric removed and replaced. This design prevents the need to replace the entire stone reservoir base.

Two infiltration trenches on the same site. The value of the vegetative buffer strip can clearly be seen.

The use of vegetative filters as a pretreatment BMP to improve long term performance of infiltration facilities cannot be stressed too much. The pictures on this page of infiltration trenches at the same site clearly show the partial clogging of the trench abutting the parking lot. The ten feet wide buffer strip between the paved surface and the trench significantly reduces the maintenance concerns associated with trench clogging.

***Of primary importance to the long term function of infiltration practices is the need to keep all contributing drainage areas stable*.** Sediment loadings into the facility must be kept to a minimum. All inspections of these facilities must include inspection for site stabilization. All areas draining to the infiltration facility must be stabilized or premature clogging of the facility will result. The infiltration system checklists recommend annual inspections for sediment accumulation. The frequency of actual maintenance activities depend on loadings from contributing drainage areas.

Clogged infiltration swale. The individual swale blocks must be dewatered before accumulated sediments are removed.

Porous paved parking lot clogged due to excess sediment on parking surface.

Porous paving or lattice block systems are somewhat unique. Reduced maintenance cannot be designed into the BMP as is done for other infiltration facilities by using biofiltration, fabrics, or forebays to help pre-treat runoff. Design options to reduce maintenance for infiltration paving is predominantly limited to using them in areas of low traffic, where paving is still necessary, or criteria specifying a certain frequency of vacuum sweeping. In general, vacuum sweeping should be done weekly with an annual pressure washing using biodegradable cleaners.

Sign at a hotel porous pavement parking lot. If paving needs to be replaced, the sign clearly states maintenance requirements.

Education is especially important in reducing OMM of infiltration paving practices. It is very important that owners are aware of the pervious nature of the paving surface. A common approval condition is to require that signs be placed around the parking area to notify all users that the surface is pervious, and that sediment tracking needs to be minimized. Signage also alerts owners of the need for in-kind replacement of the pervious pavement, if needed.

One type of porous parking surface is lattice block paving. This surface comes in modular units which can be placed down in blocks. Lattice block paving can include filter fabric under the blocks to facilitate future mainte-

Lattace block infiltration system at a commercial parking lot. The open areas are filled with pea gravel to provide support for shoe heels.

nance. When maintenance is necessary, the lattice block can be lifted up in individual sections, the filter fabric under the block replaced, and the blocks restored to their original places. However, some form of maintenance will probably be necessary on an annual basis. Porous paving facilities may require more frequent maintenance, depending on the vehicular traffic using the paved area. In heavily trafficked areas, vacuum sweeping should be done on a monthly, or at least quarterly basis.

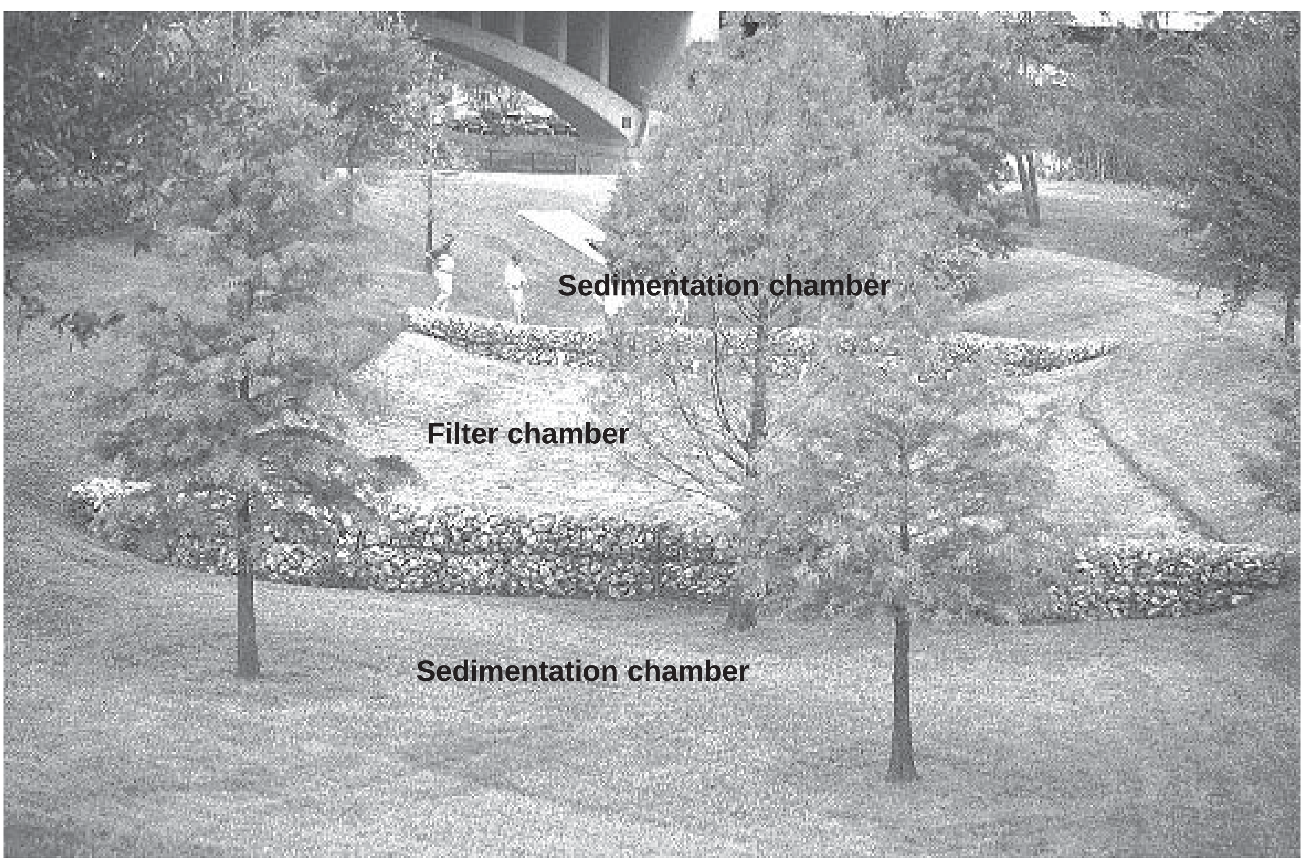
13.3 Filtration Practices

There are three distinctly different types of filtration systems, depending on whether the Austin, Delaware, or Washington, DC approaches are used. The Austin filter accepts runoff from entire drainage areas, which includes pervious areas where sediments may be finer sized than sediments from impervious areas only. The Washington, DC filter provides stormwater quantity and quality management from smaller drainage areas. The Delaware filter only provides stormwater quality treatment from impervious drainage areas. In a similar fashion, though, the frequency of maintenance of all of these facilities depends on the loadings entering the facilities, regardless of the type of facility.

All three approaches have two major components of their systems which include:

- a sedimentation chamber
- a filtration chamber

The sedimentation chamber provides a volume of storage for coarser sediments and debris. Maintenance inspections should consider the depth of materials which have been deposited in the sedimentation chamber and the potential for those trapped materials to



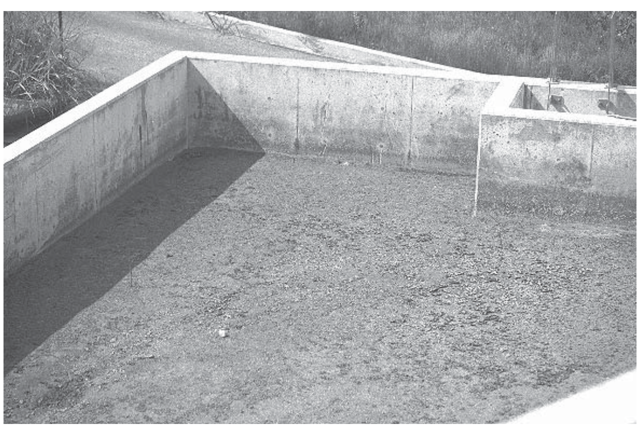
Austin sand filter serving a commercial facility. The sediment chambers are on both sides of the filter with the sand filter accepting flow through the gabion baskets.

migrate to the filtration chamber. The depth of accumulated sediments will be relatively easy to measure in all three types of facilities.

A. Austin Sand Filter

The sedimentation chamber for the Austin sand filter is designed for larger drainage areas and normally remains dry between storms. Consequently, it is normally maintained in the same fashion and with the same equipment as a dry detention facility. The frequency of maintenance depends on the stabilization of soils in the contributing watersheds. Maintenance of the sedimentation chamber is generally not needed more frequently than every five to ten years. It is important that access be provided to the sedimentation chambers for maintenance equipment to enter and perform needed maintenance.

The frequency of maintenance for the filter component of the Austin sand filter depends on the magnitude of the incoming pollutant loadings. However, in general, filters may require cleanout every year. The finer sediments may be raked from the surface of the sand and removed, or a flat bottom shovel could skim the surface of the sand to reestablish sand permeability.



Filtration chamber of an Austin sand filter showing overflow spillway. The sand media needs to be inspected regularly to determine if design permeabilities are reduced.

Delaware sand filter showing both the sedimentation and filtration chambers. The sedimentation chamber is permanently filled with water to prevent resuspension of the accumulated sediments.

B. Washington, DC and Delaware Sand Filters

The Washington, DC and the Delaware sand filter sedimentation chambers are normally wet. As such, the accumulated material will be wet and removal is best accomplished by using vacuum type equipment. In general, the volumes of water to be removed from each system are fairly small since the facilities serve smaller drainage areas than the Austin approach. This makes vacuuming a practical alternative. The frequency of vacuuming will depend on the loading contributed from the drainage areas. However, experience indicates that maintenance cleanout of the sedimentation chambers is not often needed in less than 10 years of active service.

The filtration chambers are more sensitive than the sedimentation chambers to clogging by sediments and other fine grained materials, such as oils and greases. While the sedimentation chamber functions primarily through gravity settling of the incoming materials, the filtration chamber is where filtering of pollutants occurs. This chamber will be more effective at removal of the finer sediments, which will be retained in the top several inches of the filter media.

Evidence of scour at the entrance to the filtration chamber from the sedimentation chamber. The connecting areas between chambers should be protected with a nonerosive material, such as stone or a splash pad.

The filtration chamber will need maintenance on a much more frequent basis than will the sedimentation chamber. If the sand filter is in an area with a significant pollutant loading, filter maintenance may be needed at least twice per year to ensure that the design flows travel through the facility. Diminished permeability of the sand will result in more frequent overflows into the conventional drainage system with less stormwater treatment. Replacement of the filter media is most easily accomplished with a flat bottom shovel to remove the accumulated materials. It will be fairly easy to see the depth of penetration of the pollutants and how much filter media needs removal. Usually, it is not necessary to replace all of the filter media, only the top layer.

Sand filter in Auckland, New Zealand. The sand filter serves a commercial parking lot. Vegetation growing in the filtration chamber may indicate a need for maintenance.

C. Information Applicable to all Three Filter Designs

When portions of the filter media must be replaced, only materials which meet the stormwater program's filter specifications should be used. There is a lot of research being done

Waste oil was dumped in this Delaware sand filter and sealed the filter media almost immediately. The top several inches of sand had to be replaced. On the good side, if the filter were not present, the oil would have been discharged on the community beach.

with alternative filter media such as compost, activated carbon, alum, etc. If the approving agency allows or specifies an alternative filter media as a replacement, there must be documentation in the inspection and owner's files on the use of a media different than specified on the approved plans. Most commonly used at this time for filter media sand is ASTM designation C-33 concrete sand.

Depending on the pollutants which can be expected in the filter system, testing of the material to be removed should be done to determine a suitable location for its disposal. In general, existing information indicates that disposal at a landfill is appropriate, but if the filtration facility serves an industrial facility, the sediments should be tested to determine if they are considered hazardous materials. There is a greater discussion of sediment testing and disposal in **Chapter 9**.

Stenciled pollution message adjacent to a filtration facility.

As with all stormwater management facilities, there is always the potential for vandalism. This can include damage to the facility itself, theft of facility components, or illegal dumping of waste products such as waste oil. These problems must be expected, and although not specifically anticipated, remedial action must be quickly accomplished.

A primary method to reduce vandalism is a community education program explaining stormwater pollution generation, the importance of BMPs such as filter systems, and the need to limit pollutant entry into BMPs. One component of this education program could be stenciling of the inlets to the filter. This may limit some individuals conducting the vandalism through ignorance of the facility's purpose.

Other maintenance concerns such as scour, leakage, spalling of concrete, cracks in concrete or grates need to be addressed when they are discovered. Washington, DC and Delaware filter systems have a permanent pool of water in the sedimentation chambers. If these chambers become dry, there is leakage, and the leakage must be stopped for the facility to function correctly. If the leaking area

Delaware filtration facility subject to live loads at a gasoline station.

cannot be identified, a dye test may be necessary to track the flow of water in the leaking chamber. In addition, all three of these types of filters use concrete in their construction. Concrete will deteriorate over time, especially if subject to live loads. The concrete must be routinely inspected, and repaired when necessary.

13.4 Biofiltration Systems

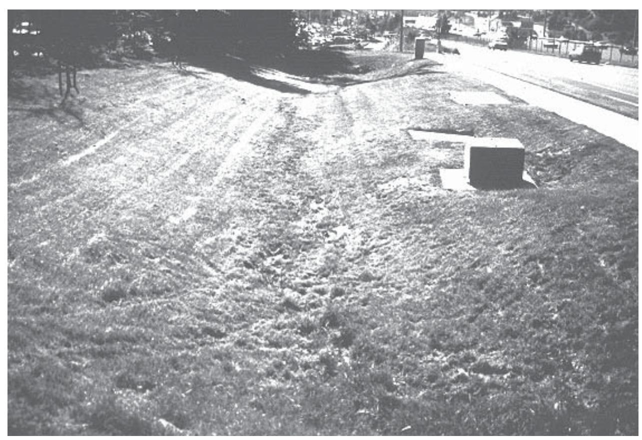
Biofiltration facilities treat runoff by filtering it through dense growths of vegetation. This filtering can be done by passing stormwater through a vegetated swale or through a designed buffer strip. Biofiltration functions rely primarily on flow traveling through the facility in a dispersed condition, preventing concentrated flow of runoff. Besides vegetative filtration, treatment in biofilters often also relies upon infiltration of runoff into underlying soils. Therefore, maintenance of biofiltration facilities is primarily concerned with:

- Maintenance of dispersed flow through the biofilter.
- Maintaining a thick growth of vegetation.
- Preventing undesired overgrowth vegetation from taking over the area.
- Removal of accumulated sediments.
- Debris removal.

Well maintained biofiltration swale serving a commercial development. There is some evidence of oil staining of the vegetation.

Maintenance of dispersed flow through the biofiltration facility is critical if its stormwater treatment effectiveness is to be maintained. Concentrated flow travels at a higher velocity than does dispersed flow, and may transport pollutants through the biofiltration system before they are removed from the runoff.

A dense growth of vegetation enhances biofiltration facility performance for stormwater treatment. Therefore, vegetation maintenance will require close attention by system owners or operators. Mowing is needed on a periodic basis, but mowing must be correctly done. Mowing grass too short will damage the grass, increase runoff flow velocities, and thereby decrease pollutant removal effectiveness. If the grass grows too tall, it may lie down during a storm instead of filtering runoff, also decreasing treatment effectiveness.



Biofiltration swale showing mowing wear and other signs of spotty vegetation demonstrating the need for maintenance.

Inspections must be done to ensure that the desired vegetation remains in the facility. The invasion of undesired vegetation can occur if site conditions promote its growth. In some situations the replacement of the planted vegetation by a volunteer species may be beneficial, but only if the invasive species pro-

Biofiltration swale with little slope, poor drainage, and baseflow. The swale is well vegetated with wetland plants.

vides equal or increased water quality benefits and is accepted by the owners of the site. If site slopes are very flat, the biofiltration facility could become dominated by wetland plants. The dense growth of wetland plants may be desired for stormwater treatment and also will reduce the typical mowing costs associated with biofiltration facilities. ***In this situation, the maintenance file documents the shift in the plant community and provide guidelines for how to take care of the modified site condition***.

Sediments will accumulate in biofiltration systems and their removal may be the most expensive aspect of biofiltration maintenance.

Sediment accumulation in a biofiltration facility reduces the effectiveness of that facility in removing pollutants. This swale is in need of maintenance to reestablish desired water quality control conditions.

When sediments are to be removed, it is essential to restore the slope and elevations to the originally constructed condition. Sediment removal will necessitate disturbance of the vegetation in the facility, so steps will have to be taken to reestablish the vegetation upon completion of sediment removal. Erosion control in the contributing drainage area also will be necessary to prevent scour of the facility until there is once again a dense stand of vegetation. Examples of erosion control techniques are shown in Chapter 6.

Sediment may also impeding effective performance of a biofiltration facility by clogging its inlets, preventing design storms from being treated in the facility. If stormwater backs up into the upstream drainage area, overflow may occur to an area not designed to accept additional flow. In this situation, erosion and site instability may result from an inlet becoming clogged with sediments.

A clogged curb cut impedes flow entering the biofiltration system. A better design would have a wider opening with a small vertical drop to prevent sediment clogging of the opening.

Similar to other types of practices, debris removal is an ongoing maintenance function at all biofiltration systems. Debris, if not removed, can block inlets or outlets, cause flow to become concentrated, and can be unsightly if located in a visible location. Inspection and removal of debris should be done on a monthly

An unmaintained, but well vegetated biofiltration system. Debris needs to be removed from the facility.

basis, but debris should be removed whenever it is observed on site.

Just as it is important to know when a facility needs to be maintained, it is important to know when you don't have to do maintenance. The original plan for the site provides the best information at that time on the design and construction of the biofiltration facility. Over time the facility may change in appearance and function. These changes may not necessarily be bad. Having a knowledgeable inspector conduct regular inspections may be one way to allow a facility to evolve into an improved facility with reduced maintenance costs. The emergence of wetland

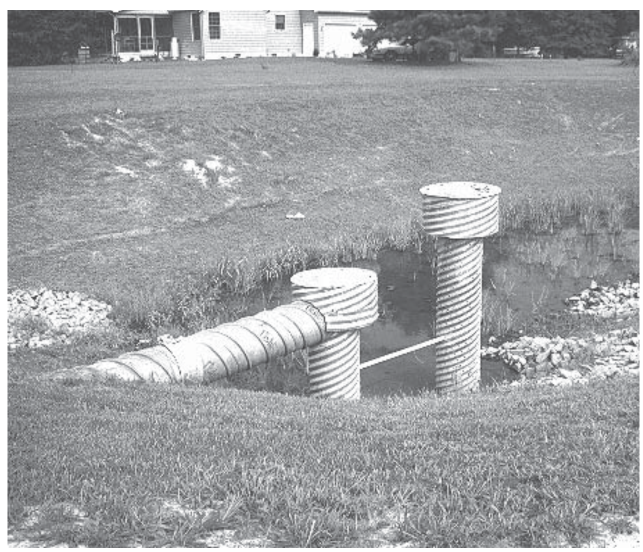
This is a natural well vegetated biofiltration facility. It is not regularly mowed but is performing its water quality function.

plants in a biofilter, or the growth of native vegetation, may improve its value and performance.

If you are unsure of the value of performing a maintenance activity, discuss the specific situation with the inspector or plan approval agency to see if there can be an improvement made to the facility.

14. GENERAL DISCUSSION

If there is any confusion about the type of stormwater management facility, it's purpose, or what specific maintenance activities are important, ASK FOR HELP! Stormwater systems can be simple in concept and function, but they can also be complex and confusing to the average individual who is far too often responsible for the facility's long term performance.



The design and operation of this facility will need to be clearly understood if effective maintenance is to occur. The taller riser contains a pump to drain the water quality volume to a higher elevation for discharge.

The inspection agency and approval agency must be available and receptive to public requests for assistance with stormwater management system operation, maintenance, and management. Often, this technical assistance will include conducting site inspections with the owner or operator to go over the approved plan, discussing maintenance inspection checklists, and providing advice to the owner or operator.

It is expected by this time, that the inspector knows to ask the plan review agency about specific aspects of facility design and construction, but that information must also be transmitted to the eventual owner/operator. A site meeting between the inspector and owner upon the owner's assumption of maintenance responsibility is very important. At this time, checklists can be given to the owner along with other educational information that may provide the owner with increased awareness about the need for proper maintenance and how it can be accomplished. At the same time, the inspector should give the owner a list of individuals who can provide assistance if problems are encountered.

Design and approval of a stormwater management system is done to the best degree possible without complete awareness of individual site development characteristics. In addition, development of a specific site may necessitate a different approach to stormwater management. In such situations, the approved plan is a springboard to water resources protection. As the developed site matures, changes may be necessary to the stormwater facility. A good relationship between the approval agency, inspection agency, owner, and operator can provide the flexibility needed to assure resource protection while allowing consideration of specific site conditions. ***Communication and commitment are essential for assuring the long term operation, maintenance, and management of stormwater management systems*.**

The operation of this stormwater management system appears very confusing. The inspector must work closely with the owner/operator to ensure that proper performance is maintained.

APPENDIX 7-1

Operation, Maintenance, and Management Inspection Checklist for Ponds

Operation and Maintenance Inspection Report for Stormwater Management Ponds
(Adapted from Anne Arundel County, Maryland)

Inspector Name ____________________________ Community ____________________________
Inspection Date ____________________________ Address ____________________________
Stormwater Pond ____________________________
Normal Pool _______ ____________________________
Normally Dry _______ Watershed ____________________________

Items inspected	Checked Yes	Checked No	Maintenance Needed Yes	Maintenance Needed No	Inspection Frequency	Remarks
I, Pond components						
A. Embankment and Emergency spillway					A,S	
1. Vegetation and ground Cover adequate						
2. Embankment erosion						
3. Animal burrows						
4. Unauthorized plantings						
5. Cracking, bulging, or sliding of dam						
a. Upstream face						
b. Downstream face						
c. At or beyond toe Upstream						
Downstream						
d. Emergency spillway						
6. Pond, toe & chimney drains clear and functioning						
7. Seeps/leaks on downstream face						
8. Slope protection or riprap failures						
9. Vertical and horizontal alignment of top of dam as per "As-Built" plans						
10. Emergency spillway clear of obstructions and debris						
11. Other (specify)						
B. Riser and principal spillway					A	
Type: Reinforced concrete ___ Corrugated pipe ___ Masonry ___						
1. Low flow orifice obstructed						
2. Low flow trash rack						
a. Debris removal necessary						
b. Corrosion control						
3. Weir trash rack maintenance						
a. Debris removal necessary						
b. Corrosion control						

Inspection Frequency Key A=Annual, M=Monthly, S=After major storm

Items inspected	Checked Yes	Checked No	Maintenance Needed Yes	Maintenance Needed No	Inspection Frequency	Remarks
4. Excessive sediment accumulation inside riser						
5. Concrete/Masonry condition Riser and barrels a. Cracks or displacement						
b. Minor spalling (<1")						
c. Major spalling (rebars exposed)						
d. Joint failures						
e. Water tightness						
6. Metal pipe condition						
7. Control valve a. Operational/exercised						
b. Chained and locked						
8. Pond drain valve a. Operational/exercised						
b. Chained and locked						
9. Outfall channels functioning						
10. Other (specify)						
C. Permanent pool (wet ponds)					M	
1. Undesirable vegetative growth						
2. Floating or floatable debris removal required						
3. Visible pollution						
4. Shoreline problems						
5. Other (specify)						
D. Sediment forebays						
1. Sedimentation noted						
2. Sediment cleanout when depth < 50% design depth						
E. Dry pond areas					M	
1. Vegetation adequate						
2. Undesirable vegetative growth						
3. Undesirable woody vegetation						
4. Low flow channels clear of obstructions						
5. Standing water or wet spots						
6. Sediment and/or trash accumulation						
7. Other (specify)						
F. Condition of outfalls into pond					A,S	
1. Riprap failures						
2. Slope erosion						
3. Storm drain pipes						
4. Endwalls/headwalls						
5. Other (specify)						
G. Other					M	
1. Encroachments on pond or easement area						

Inspection Frequency Key A=Annual, M=Monthly, S=After major storm

Items inspected	Checked Yes	Checked No	Maintenance Needed Yes	Maintenance Needed No	Inspection Frequency	Remarks
2. Complaints from residents (describe on back)						
3. Aesthetics a. grass mowing required						
b. graffiti removal needed						
c. Other (specify)						
4. Any public hazards (specify)						
5. Maintenance access						
H. Constructed wetland areas					A	
1. Vegetation healthy and growing						
2. Evidence of invasive species						
3. Excessive sedimentation in wetland area						

Inspection Frequency Key A=Annual, M=Monthly, S=After major storm

II. Summary

1. Inspectors Remarks: ______________________________

____

____

____

____

____

____

____

____

2. Overall condition of Facility (Check one)

______ Acceptable

______ Unacceptable

3. Dates any maintenance must be completed by:

____

____

____

____

APPENDIX 7-2

Operation, Maintenance, and Management Inspection Checklists for Infiltration Practices:

Infiltration Basin Maintenance Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date ________________ Time ____________________

Project ____

Location ___________________________________

Individual Conducting the Inspection ________________________ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

Item	Frequency	Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Basin bottom clear of debris		______	______
Inlet clear of debris		______	______
Outlet clear of debris		______	______
Emergency spillway clear of debris		______	______
2. Sediment traps or forebays	(Annual)		
Obviously trapping sediment		______	______
greater than 50% of storage volume remaining		______	______
3. Vegetation	(Monthly)		
mowing done when needed		______	______
Fertilized per specifications		______	______
No evidence of erosion			
4. Dewatering	(Monthly)		
Basin dewaters between storms		______	______
5. Sediment cleanout of basin	(Annual)		
No evidence of sedimentation in basin		______	______
Sediment accumulation does not yet require cleanout		______	______
6. Inlets	(Annual)		
Good condition		______	______
No evidence of erosion		______	______
7. Outlets/overflow spillway	(Annual, After Major Storm)		
Good condition, no need for repair		______	______
No evidence of erosion		______	______
8. Structural repairs	(Annual, After Major Storm)		
Embankment in good repair		______	______
Side slopes are stable		______	______
No evidence of erosion		______	______

Inspection Frequency Key Annual, Monthly, After major storm

		Satisfactory	Unsatisfactory
9. Fences/access repairs	(Annual)		
Fences in good condition		______	______
No damage which would allow undesired entry		______	______
Access point in good condition		______	______
Locks and gate function adequate		______	______

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections ___________
Correct noted facility deficiencies by ______________________

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or improvements.

Site reinspection accomplished on ________________________

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

____

____
Signature of Inspector

Infiltration Trench Maintenance Inspection Report Form

Adapted from the State of Maryland Inspector's Guidelines Manual

Date ________________ Time ____________________

Project ____

Location __________________________________

Individual Conducting the Inspection _______________________ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

Item	Frequency	Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Trench surface clear of debris		______	______
Inlet areas clear of debris		______	______
Inflow pipes clear of debris		______	______
Overflow spillway clear of debris		______	______
2. Sediment traps, forebays, or pretreatment swales	(Annual)		
Obviously trapping sediment		______	______
greater than 50% of storage volume remaining		______	______
3. Vegetation	(Monthly)		
mowing done when needed		______	______
Fertilized per specifications		______	______
No evidence of erosion			
4. Dewatering	(Monthly)		
Trench dewaters between storms		______	______
5. Sediment cleanout of trench	(Annual)		
No evidence of sedimentation in trench		______	______
Sediment accumulation does not yet require cleanout		______	______
6. Inlets	(Annual)		
Good condition		______	______
No evidence of erosion		______	______
7. Outlets/overflow spillway	(Annual)		
Good condition, no need for repair		______	______
No evidence of erosion		______	______

Inspection Frequency Key Annual, Monthly, After major storm

	Satisfactory	Unsatisfactory
8. Aggregate repairs (Annual)		
Surface of aggregate clean	______	______
Top layer of stone does not need replacement	______	______
Trench does not need rehabilitation	______	______
9. Vegetated surface (Monthly)		
No evidence of erosion	______	______
Perforated inlet functioning adequately	______	______
Water does not stand on vegetative surface	______	______
Good vegetative cover exists	______	______

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections ___________
Correct noted facility deficiencies by ______________________

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or improvements.

Site reinspection accomplished on ________________________

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

____

____
Signature of Inspector

Infiltration Dry Well Maintenance Inspection Report Form

Date ________________ Time ____________________

Project ____

Location ___________________________________

Individual Conducting the Inspection ________________________ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

Item	Frequency	Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Roof drains and downspouts clean		______	______
2. Vegetation on top of dry well	(Monthly)		
mowing done when needed		______	______
Fertilized per specifications		______	______
No evidence of erosion		______	______
3. Dewatering	(Monthly)		
Dry well dewaters between storms		______	______
4. Inlets	(Annual)		
Good condition of down spouts		______	______
No evidence of deterioration		______	______
Roof gutters drain correctly into dry well		______	______
5. Outlets/overflow spillway	(Annual)		
Good condition, no need for repair		______	______
No evidence of erosion		______	______

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections ___________
Correct noted facility deficiencies by ______________________

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or improvements.

Site reinspection accomplished on ________________________

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

________________________________ ____________________________________
Signature of Inspector

Infiltration Paving Maintenance Inspection Report Form

Date________________ Time____________________

Project____

Location___________________________________

Individual Conducting the Inspection _______________________ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

	Satisfactory	Unsatisfactory
1. Debris on infiltration paving parking area (Monthly)		
Paving area clean of debris	________	________
2. Vegetation (any buffer areas or pervious areas in drainage area) (Monthly)		
mowing done when needed	________	________
Fertilized per specifications	________	________
No evidence of erosion	________	________
3. Dewatering (Monthly)		
Infiltration paving dewaters between storms	________	________
4. Sediments (Monthly)		
Area clean of sediments	________	________
Area vacuum swept on a periodic basis	________	________
5. Structural condition (Annual)		
No evidence of surface deterioration	________	________
No evidence of rutting or spalling	________	________

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections ___________
Correct noted facility deficiencies by ______________________

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or improvements.

Site reinspection accomplished on ________________________

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

________________________________ ____________________________________
Signature of Inspector

Infiltration Swale Well Maintenance Inspection Report Form

Date________________ Time____________________

Project____

Location___________________________________

Individual Conducting the Inspection ________________________ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

		Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Swales and contributing areas clean of debris		____________	____________
2. Vegetation	(Monthly)		
mowing done when needed		____________	____________
Fertilized per specifications		____________	____________
No evidence of erosion		____________	____________
Minimum mowing depth not exceeded		____________	____________
3. Dewatering	(Monthly)		
Swale dewaters between storms		____________	____________
4. Check dams or energy dissipators	(Annual, After Major Storm)		
No evidence of flow going around structures		____________	____________
No evidence of erosion at downstream toe		____________	____________
5. Sediment deposition	(Annual)		
Swale clean of sediments		____________	____________
6. Outlets/overflow spillway	(Annual, After Major Storm)		
Good condition, no need for repair		____________	____________
No evidence of erosion		____________	____________

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections ___________

Correct noted facility deficiencies by ______________________

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections.

Site reinspection accomplished on ________________________

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

________________________________ ____________________________________

Signature of Inspector

APPENDIX 7-3

Operation, Maintenance, and Management Inspection Checklist for Filtration Practices

Filtration Facility Maintenance Inspection Report Form

Date ________________ Time ____________________

Project ____

Location ___________________________________

Individual Conducting the Inspection ________________________ "As Built" Plans available Y/N

Warning: If filtration facility has a watertight cover; be careful regarding the possibility of flammable gases within the facility. Care should be taken lighting a match or smoking while inspecting facilities that are not vented.

Inspection frequency shown in parentheses after item being considered

Item	Frequency	Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Contributing areas clean of debris		______	______
Filtration facility clean of debris		______	______
Inlets and outlets clear of debris		______	______
2. Vegetation	(Monthly)		
Contributing drainage area stabilized		______	______
No evidence of erosion		______	______
Area mowed and clippings removed			
3. Oil and grease	(Monthly)		
No evidence of filter surface clogging		______	______
Activities in drainage area minimize oil & grease entry		______	______
4. Water retention where required	(Monthly)		
Water holding chambers at normal pool		______	______
No evidence of leakage		______	______
5. Sediment deposition	(Annual)		
Filtration chamber clean of sediments		______	______
Water chambers not more than 1/2 full of sediments		______	______
6. Structural components	(Annual)		
No evidence of structural deterioration		______	______
Any grates are in good condition		______	______
No evidence of spalling or cracking of structural parts		______	______
7. Outlets/overflow spillway	(Annual)		
Good condition, no need for repair		______	______
No evidence of erosion (if draining into a natural channel)		______	______

Inspection Frequency Key Annual, Monthly, After major storm

		Satisfactory	Unsatisfactory
8. Overall function of facility	(Annual)		
No evidence of flow bypassing facility		______	______
No noticeable odors outside of facility		______	______

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections ___________
Correct noted facility deficiencies by ______________________

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or repairs.

Site reinspection accomplished on ________________________

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

________________________________ ____________________________________
Signature of Inspector

APPENDIX 7-4

Operation, Maintenance, and Management
Inspection Checklist
for
Biofiltration Practices

Biofiltration Facility Maintenance Inspection Report Form

Date________________ Time____________________

Project____

Location___________________________________

Individual Conducting the Inspection ______________________ "As Built" Plans available Y/N

Inspection frequency shown in parentheses after item being considered

Item	Frequency	Satisfactory	Unsatisfactory
1. Debris cleanout	(Monthly)		
Biofilters and contributing areas clean of debris		______	______
No dumping of yard wastes into biofilter		______	______
Litter (branches, etc.) have been removed		______	______
2. Vegetation	(Monthly)		
Plant height not less than design water depth		______	______
Fertilized per specifications		______	______
No evidence of erosion		______	______
Grass height not greater than 6 inches		______	______
Is plant composition according to approved plans		______	______
No placement of inappropriate plants		______	______
3. Dewatering	(Monthly)		
Biofilter dewaters between storms		______	______
No evidence of standing water		______	______
4. Check dams/energy dissipators/sumps	(Annual, After Major Storm)		
No evidence of sediment buildup		______	______
Sumps should not be more than 50% full of sediment		______	______
No evidence of erosion at downstream toe of drop structures		______	______
5. Sediment deposition	(Annual)		
Swale clean of sediments		______	______
Sediments should not be > than 20% of swale design depth		______	______
6. Outlets/overflow spillway	(Annual, After Major Storm)		
Good condition, no need for repair		______	______
No evidence of erosion		______	______
No evidence of any blockages		______	______
7. Integrity of biofilter	(Annual)		
Biofilter has not been blocked or filled inappropriately		______	______

Inspection Frequency Key Annual, Monthly, After major storm

Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections ___________
Correct noted facility deficiencies by ______________________

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections.

Site reinspection accomplished on ________________________

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

________________________________ ____________________________________
Signature of Inspector

Chapter 8
Costs and Financing of Stormwater Facility Operation and Maintenance

1. OVERVIEW

Even if a stormwater management program has established effective institutional mechanisms to help assure that stormwater systems are operated and maintained properly, problems can arise because of inadequate knowledge about the costs of maintenance. Annual program budgets must include adequate staffing and financial resources to conduct the maintenance activities needed to assure that stormwater systems operate properly. Additionally, the stormwater program must assure that financial mechanisms are implemented to provide the needed funding.

The fundamental role that proper budgeting and financing plays in the successful performance of effective stormwater system maintenance cannot be overemphasized. The specific objectives of this chapter are:

- To provide operating and maintenance cost information from several stormwater programs around the country.
- To provide methods by which stormwater programs can estimate operation and maintenance costs.
- To provide general information on various alternative methods of financing stormwater system operation, maintenance, and management.

1.1. Intended Readers

This chapter is intended to provide information on the costs of stormwater system operation, maintenance, and management to:

- **Stormwater system owners.**
- **Directors of stormwater utilities, public works, stormwater programs, and other public and private agencies responsible for stormwater system maintenance.**
- **Purchasing agents, managers, and directors.**

The chapter also discusses various methods of obtaining adequate public and private funds for required stormwater system operation, maintenance, and management. This information is intended specifically for:

- **Elected officials and other leaders of state, regional, and local governments responsible for stormwater system maintenance.**
- **Stormwater program administrators, business administrators, comptrollers, financial directors, and other public and private sector officials responsible for financing stormwater system maintenance.**

2. STORMWATER SYSTEM MAINTENANCE COSTS

To develop sound stormwater system operation, maintenance, and management budgets and determine adequate funding levels, a comprehensive data base of OMM costs is needed. Unfortunately, there is very little hard data on the actual costs of stormwater system OMM, especially for stormwater treatment BMPs. ***This chapter will present data on general OMM costs along with specific cost data from several stormwater programs around the country***.

It is important to remember that the cost of stormwater system OMM is very site specific. Factors that determine the frequency, type, and cost of OMM include the type and size of BMP, use of source controls, land use, contributing drainage area, rainfall characteristics, climate, vegetation growing system, maintenance access, and disposal requirements.

Table 8-1 presents cost estimates for various equipment and materials used in typical stormwater management system OMM. Costs are provided both for equipment purchase and rental. ***In many cases, renting equipment, is a preferred alternative. This is especially true for infrequently used equipment or larger, very expensive equipment. Additionally, local governments often find it advantageous to contract for the use of highly specialized equipment since staff may not have the experience needed to operate it***. Purchasing these types of equipment, and especially more commonly used equipment, may be justified when it can be used for activities other than stormwater facility maintenance, such as by road, public works, or recreation departments. For larger equipment, it may be less expensive to lease for a short time instead of renting by the day.

These cost estimates are intended to provide generalized cost data to those in both the public and private sectors involved either in the actual OMM of stormwater systems, or in the planning, budgeting and financing for stormwater system OMM. The reader should develop more detailed cost estimates based upon local data or data pertaining to a specific program or type of stormwater system. Sources of more specific data include local equipment sales, lease, and/or rental companies, and local maintenance and construction contractors. Valuable information can be obtained from local government stormwater, public works, parks, or road departments. Consultation and coordination between these various departments within local governments or private companies is strongly recommended.

Table 8-2 summarizes the estimated person-hours associated with many of the more common stormwater system operation, maintenance, and management activities. These values can be used with applicable personnel rates to determine labor costs for a specific stormwater program or facility. The reader should note that the estimates are based on the entire area of a stormwater system. Additionally, dry BMPs are assumed to be entirely covered with grass which requires regular mowing, fertilizer, and other management. Appropriate adjustments should be made for wet BMPs and for facilities that are larger than one acre.

In addition to labor and materials costs, an additional allowance needs to be made for the disposal of trash, debris, leaves, and sediments. These costs can be minimized by having a dedicated area where materials can be composted or where sediments can be dewatered and reused. These areas can either be on-site near the stormwater system or at a centrally located materials yard within the community. Disposal of these materials must comply with federal, state, and/or local regulations **(See Chapter 9)**. Accordingly, costs and requirements can vary widely.

3. OMM COSTS FROM SPECIFIC STORMWATER MANAGEMENT PROGRAMS

This section will present cost information from

TABLE 8 -1.
Stormwater System OMM Equipment and Material Costs (1997).

GRASS MAINTENANCE EQUIPMENT		
EQUIPMENT	PURCHASE	RENT (Per Day)
Hand mower	$300 - $500	$25 - $50
Riding mower	$3,000 - $7,000	$75 - $150
Tractor mower	$20,000 - $30,000	$150 - $450
Trimmer/edger	$200 - $500	$25 - $35
Spreader	$100 - $200	$20 - $30
Chemical sprayer	$200 - $500	$25 - $40
VEGETATIVE COVER MAINTENANCE EQUIPMENT		
Hand saw	$15 - $20	$5
Chain saw	$300 - $800	$15 - $35
Pruning shears	$25 - $40	$5
Shrub trimmer	$200 - $300	$25 - $35
Brush chipper	$2,000 - $10,000	$100 - $300
SEDIMENT, DEBRIS, AND TRASH REMOVAL EQUIPMENT		
Vactor truck	$100,000 - $250,000	$700 - $1200
Front end loader	$60,000 - $120,000	$250 - $500
Backhoe	$50,000 - $100,000	$250 - $500
Excavator	>$100,000	$400 - $1,000
Grader	>$100,000	$400 - $1,000
TRANSPORTATION EQUIPMENT		
Van	$18,000 - $30,000	$50 -$100
Pickup truck	$15,000 - $25,000	$50 - $100
Dump truck	$40,000 - $80,000	$100 - $200
Light duty trailer	$3,000 - $6,000	$50 - $100
Heavy duty trailer	$10,000 - $20,000	$100 - $250

TABLE 8 -1.

Stormwater System OMM Equipment and Material Costs (Cont.).

MISCELLANEOUS EQUIPMENT		
EQUIPMENT	PURCHASE	RENT (Per Day)
Shovel	$15	$5
Rake	$15	$5
Pick	$20	$5
Wheel barrow	$100 - $250	$15 - $25
Portable compressor	$800 - $2,000	$50 - $150
Portable generator	$750 - $2,000	$50 - $150
Concrete mixer	$750 - $1,500	$50 - $100
Welding equipment	$750 - $2,000	$50 - $100

MATERIALS	
MATERIAL	PURCHASE
Topsoil	$35 - $50/cubic yard
Fill soil	$15 - $30/cubic yard
Grass seed	$5 - $10/pound
Soil amenties (fertilizer, lime, etc)	$0.10 - $0.25/sq. ft.
Chemicals (ie,pesticides, herbicides, etc)	$10 - $30/gallon
Mulch	$25 - $40/cubic yard
Dry mortar mix	$5/50 pound bag
Concrete delivered	$60 - $100/cubic yard
Machine/motor lubricants	$5 - $10/gallon
Paint	$20 - $40/gallon
Paint remover	$10 - $20/gallon

TABLE 8 - 2.

Typical Hours Needed To Perform Stormwater OMM Tasks.

PREVENTATIVE MAINTENANCE TASKS (Values expressed in person-hours)		
TASK	SMALL FACILITY (Total area < 0.25 acre)	LARGE FACILITY (Total area > 1 acre)
Grass cutting	1	1 - 4
Grass management	0.5	1 - 2
Trash & debris removal	0.5	1 - 2
Sediment removal	4	6 - 10
Mobilization	1	1
Inspection & reporting	1	2
CORRECTIVE MAINTENANCE TASKS		
Trash & debris removal	4	6 - 10
Sediment removal	8 -12	8 - 40
Dewatering	4	8 - 16
Aquatic vegetative mgmt.	4	6 - 16
Structural repairs	24	36 - 72
Erosion repair	1 - 4	3 - 8
Fence repair	2 - 4	4 - 10
Snow & ice removal	1 - 4	2 - 6
Mosquito extermination	1	2 - 4
Mobilization	2	2 - 4
AESTHETIC MAINTENANCE TASKS		
Grass trimming	0.5 - 1	1 - 4
Weed control	0.5 - 1	2 - 4
Landscape maintenance	1 - 2	2 - 8
Graffiti removal	2 - 4	4 - 8

country associated with their facility operation, maintenance, and management activities. Because the information from each program varies so greatly, information from each program will be presented separately and in different formats.

3.1. City of Orlando, Florida

Orlando has required the treatment of stormwater since 1984, with recent emphasis on retro-fitting older drainage systems to reduce stormwater pollutant loadings into the City's lakes. The City conducts a wide range of operation, maintenance, and management activities on its stormwater systems and has a very active lake management program. Summarized below are costs associated with major OMM activities:

Activity	Cost
Herbicide (Rodeo) application to ditch bottoms	$170.00 per acre
Street grass control with herbicide (Roundup)	$ 6.40 per city block
Ditch mowing by hand using weed-eaters and mowers	$ 60.00 per acre
Ditch mowing by large tractor	$ 12.00 per acre
Cleaning of stormsewers and catch basins with Vactor	$160.00 per hour
Repair of structures (less materials)	$ 50.00 per hour

3.2. City of Fresno, California

Fresno developed and is implementing a stormwater master plan which relies upon regional stormwater retention (infiltration) facilities. The city's facilities are classified as "stormwater systems", "recharge systems" or " fully landscaped systems", with the latter also serving as 10 to 20 acre parks. The respective annual OMM costs for these facilities are $125/acre (stormwater systems), $197/acre (recharge systems), and $1,506/acre (landscaped systems). When accumulated sediments need to be removed from any of these systems the annual cost is approximately $275/acre. Table 8-3 provides a more detailed summary of these costs.

3.3. Somerset County, New Jersey

The primary focus of the stormwater management program in Somerset County is flood control. The program, which began in 1975, operates an extensive flood control network with radiotelemetry controls of its main drainage structures. As part of its stormwater management system, a large number of dry detention basins, with concrete low flow channels, have been constructed. Maintenance of these systems primarily consists of grass trimming and mowing. When mowing is performed, erosion problems are identified and repaired, debris and litter are removed, as is sediment which has accumulated in the low flow channel. The County is responsible for the OMM of 52 dry detention systems with a land area of 164.5 acres. These range in size from 0.5 to 21.5 acres.

Until 1992, the County used its own maintenance crew to perform all OMM operations. In

TABLE 8 - 3.

Maintenance Activities and Costs for Stormwater Management Systems in Fresno, California (1996).

STORMWATER SYSTEMS (No landscaping, 10 systems, 92.2 acres)		
Activity	**Cost**	
Weeding	$110/acre/year	
Special (erosion control)	$ 6/acre/year	
Extra work (structural repairs)	$ 4/acre/year	
Miscellaneous	$ 4/acre/year	
FULLY LANDSCAPED SYSTEMS (10 basins, 84.1 acres)		
Mowing	$770/acre/year	
Water	$416/acre/year	
Extra work (erosion, structural repairs)	$185/acre/year	
P G & E	$130/acre/year	
Rodent control	$ 5/acre/year	
RECHARGE BASINS		
Basin/Size	**Cost**	**Cost/Acre/Yr**
A - 10.0 acres	$3,500	$350
S - 26.9 acres	$4,000	$149
OO - 9.3 acres	$ 57	$ 61
AC - 10.4 acres	$2,500	$240
AE - 21.6 acres	$1,728	$ 80
BO - 15.0 acres	$4,112	$274
CL - 14.7 acres	$4,400	$299
CN - 21.0 acres	$5,000	$238
CO2 - 13.2 acres	$1,535	$116
CW - 15.3 acres	$3,602	$235

1993, the county solicited bids for the work and hired a private contractor who did an excellent job. In 1994, the county once again solicited bids and received the following bids:

Bidder	Bid Price	$/OMM Visit	$/Acre
County	$68,236	$ 312	$414.81
Bidder A	$62,200	$ 284	$378.12
Bidder B	$56,100	$ 256	$341.03
Bidder C	$51,635	$ 236	$313.89

The three bid prices include $8,000 in County costs for supervision and inspection. This cost is based on three hours of supervision/inspection per day, assuming 2 to 3 basins per day, for a total of 110 days at $25 per hour personnel costs. Based on these bids, the County awarded the work to the low bidder, a different contractor than the County had used in 1993. This contractor did not perform as well as the previous contractor. The County received many complaints from residents about the contractor's poor OMM work. Consequently, County staff performed many remedial OMM tasks resulting in $6,000 in additional costs. In 1995, the County's elected officials decided to allow the County maintenance crew to once again perform all OMM operations. ***Even though the cost was about $5,000 more than using a private contractor, advantages of using the County crew included better workmanship, quicker response time to resident requests, fewer complaints from residents, and greater accountability***.

Table 8-4 summarizes the activities and costs associated with the maintenance of 52 dry detention systems in Somerset County. The table shows the costs of maintenance for all basins and for those with an area of 2 to 2.5 acres, the size of the typical system. It also shows the costs of performing stormwater maintenance activities two, three, and five times per year.

TABLE 8 - 4.
Summary of 1994 Stormwater System OMM Costs
in Somerset County, New Jersey.

ITEM	ALL 1994 BASINS	2 - 2.5 ACRE BASINS	2 OMM/YR	3 OMM/YR	5 OMM/YR
Total cost	$62,450	$22,037	$6,039	$2,792	$53,669
Total #OMM	219	89	22	12	185
Total area	164.5	49	25.5	8	131
# Basins	52	22	11	4	37
$/OMM	$285.16	$247.61	$274.50	$232.67	$290.10
$/Acre	$379.64	$449.73	$236.82	$349.00	$409.69
$/Basin	$1,200.9	$1,001.68	$549.00	$698.00	$1,450.51
OMM/Basin	4.21	4.04	2	3	5
Acre/Basin	3.16	2.23	2.32	2	3.54
$/Acre/OM	$90.18	$111.32	$118.41	$116.33	$81.94

3.4. City of Austin, Texas

Austin, Texas began requiring the treatment of stormwater in 1984 as part of the city's program to protect its surface and ground water resources. The city's stormwater program annual budget has varied in recent years from $16.28 million in FY93-94 to $16.76 million in FY94-95 to $15.28 million in FY95-96. Stormwater OMM costs within these three budget years amounted to $3.16 million, $3.69 million, and $4.34 million. The primary funding source is from the city's stormwater utility which collected $14.87 million, $15.42 million, and $13.56 million respectively in these three budget years. Additionally, stormwater OMM funding is obtained from inspection and maintenance fees which brought in $128,241, $170,000, and $260,131. The number of employees at the utility has increased from 74 FTEs in FY93-94 to 78 in FY94-95 to 86 in FY95-96, with increased maintenance of stormwater systems accounting for five of the eight new positions in this last year.

Tables 8-5 A-E present information from the city's most recent five year stormwater maintenance plan. The city's budget also includes the following performance measures for OMM:

Outcome	1993-94	1994-95	1995-96(goal)
Removed sediments from creeks (cyds)	n/a	n/a	10,000
Restore water quality ponds	8	12	20
# restored ponds/maintenance FTE	0.8	2.0	4.0
# water quality ponds maintained	161	273	327

3.5. Urban Drainage and Flood Control District (Denver, Colorado)

The UDFCD coordinates regional stormwater management in the metropolitan Denver area, covering 1608 square miles and 36 local governments. The District charges an annual drainage fee which raises approximately $4 million per year. The District is responsible for OMM operations at selected regional, multi-jurisdictional stormwater facilities, primarily drainage conveyances and dry detention systems. The District contracts most OMM work and conducts inspections to assure that the work is performed satisfactorily.

Routine OMM activities include mowings of non-irrigated natural grasses along drainage channels, regularly scheduled collection and disposal of debris and litter from the drainageway, and unscheduled debris removal that become necessary because of large storms. Non-routine OMM activities include erosion repair and construction to rehabilitate or replace existing drainage structures.

Table 8-6 summarizes information on the cost of OMM operations conducted for the UDFCD. It is important to note that the per foot costs of maintenance varies greatly depending on the width of the channel and its associated right of way, the type of bottom, the slope of the channel sides, the type channel side slope stabilization, the type and extent of vegetation, and the ease of maintenance access.

TABLE 8 - 5 A.
City of Austin
Stormwater Maintenance Plan
FY 1995
(Note: 2X,3X,4X =two times, three times, four times).

Activity	Inventor	Estimated Need	Actual Output	Actual Budget
RESOURCE SERVICES				
Contract channel vegetation removal	300 miles	82 miles 3X	64 miles 3X	$700,000
Contract pond vegetation removal	161	161ponds 3X	136 ponds 4X	$100,000
Complaint handling	N/A	1,500	1,500	$199,169
Storm sewer locating (utility coord)	N/A	2,000 loc./yr	2,000 loc./yr	$91,152
Maintenance scheduling/planning		N/A	N/A	$206,239
Street drainage repairs	unknown	unknown	unknown	$175,000
WATERWAY MAINTENANCE				
Channel dredging/cleaning	300 miles	20miles	5 miles	$578,984
Bridge/culvert clearing	1,000	2,400	1,800	$579,384
Erosion control projects	150	150	6	$200,548
INLET MAINTENANCE				
Storm sewer inlet inspection	18,000	18,000 2X	2,000 4X	$51,073
Storm sewer inlet cleaning	18,000	13,500 2X	1,500 4X	$207,542
Storm sewer inlet filter cleaning	178	7,476	7,476	$34,048
Wet debris dewatering	N/A	300	100	$293,097
STORM SEWER MAINTENANCE				
Storm sewer repair/installation	400 miles	unknown	2,400 feet	$277,145
Storm sewer cleaning	400 miles	unknown	10,000 feet	$102,145
Storm sewer inspection	400 miles	unknown	6 miles/yr	$151,073
POND MAINTENANCE				
Water quality pond restoration	142	35	4	$212,078
Water quality/detention pond OMM	161	126	50	N/A
TOWN LAKE CLEANUP	N/A	300	120	$34,048

TABLE 8 - 5 B.
City of Austin
Stormwater Maintenance Plan
FY 1996.

Activity	Inventor	Estimated Need	Proposed Output	Proposed Budget
RESOURCE SERVICES				
Contract channel vegetation removal	300 miles	82 miles 3X	50 miles 3X	$600,000
Contract pond vegetation removal	273	273 ponds 3X	136 ponds 4X	$100,000
Complaint handling	N/A	1,650	1,650	$175,870
Storm sewer locating (utility coord)	N/A	2,330 loc./yr	2,330 loc./yr	$87,935
Maintenance scheduling/planning		N/A	N/A	$179,170
Street drainage repairs	unknown	unknown	unknown	$175,000
WATERWAY MAINTENANCE				
Channel dredging/cleaning	300 miles	20miles	8 miles	$1,010,061
Bridge/culvert clearing	1,000	2,400	1,800	$533,374
Erosion control projects	150	150	10	$342,750
INLET MAINTENANCE				
Storm sewer inlet inspection	18,000	18,000 2X	6,000 2X	$66,996
Storm sewer inlet cleaning	18,000	13,500 2X	1,900 4X	$223,319
Storm sewer inlet filter cleaning	178	8,544	8,544	$44,664
Wet debris dewatering	N/A	300	110	$89,328
STORM SEWER MAINTENANCE				
Storm sewer repair/installation	400 miles	unknown	2,400 feet	$173,991
Storm sewer cleaning	400 miles	unknown	10,000 feet	$133,991
Storm sewer inspection	400 miles	unknown	4 miles/yr	$86,996
Special projects	**N/A**	unknown	6 projects	$89,238
POND MAINTENANCE				
Water quality pond restoration	240	56	30	$542,541
Water quality/detention pond OMM	273	217	200	N/A
TOWN LAKE CLEANUP	N/A	300	140	$134,164

TABLE 8 - 5 C.
City of Austin
Stormwater Maintenance Plan
FY 1997.

Activity	Inventor	Estimated Need	Proposed Output	Proposed Budget
RESOURCE SERVICES				
Contract channel vegetation removal	300 miles	82 miles 3X	72 miles 3X	$700,000
Contract pond vegetation removal	327	327 ponds 3X	327 ponds 4X	$240,441
Complaint handling	N/A	1,825	1,825	$181,146
Storm sewer locating (utility coord)	N/A	2,650 loc./yr	2,650 loc./yr	$90,573
Maintenance scheduling/planning		N/A	N/A	$538,146
Street drainage repairs	unknown	unknown	unknown	$175,000
WATERWAY MAINTENANCE				
Channel dredging/cleaning	300 miles	20miles	9 miles	$1,100,063
Bridge/culvert clearing	1,000	2,400	2,000	$549,375
Erosion control projects	150	150	20	$228,145
INLET MAINTENANCE				
Storm sewer inlet inspection	18,000	18,000 2X	6,000 2X	$69,006
Storm sewer inlet cleaning	18,000	13,500 2X	4,500 2X	$275,018
Storm sewer inlet filter cleaning	178	8,544	8,544	$46,003
Wet debris dewatering	N/A	300	130	$112,008
STORM SEWER MAINTENANCE				
Storm sewer repair/installation	400 miles	unknown	2,600 feet	$309,011
Storm sewer cleaning	400 miles	unknown	10,500 feet	$138,011
Storm sewer inspection	400 miles	unknown	14 miles/yr	$119,005
Special projects	**N/A**	unknown	7 projects	$92,007
POND MAINTENANCE				
Water quality pond restoration	288	38	38	$207,176
Water quality/detention pond OMM	327	289	289	N/A
TOWN LAKE CLEANUP	N/A	300	170	$46,[illegible]

TABLE 8 - 5 D.
City of Austin
Stormwater Maintenance Plan
FY 1998.

Activity	Inventor	Estimated Need	Proposed Output	Proposed Budget
RESOURCE SERVICES				
Contract channel vegetation removal	300 miles	82 miles 3X	78 miles 3X	$750,000
Contract pond vegetation removal	382	382 ponds 3X	382 ponds 4X	$240,441
Complaint handling	N/A	2,000	2,000	$186,580
Storm sewer locating (utility coord)	N/A	3,000 loc./yr	3,000 loc./yr	$93,290
Maintenance scheduling/planning		N/A	N/A	$186,580
Street drainage repairs	unknown	unknown	unknown	$175,000
WATERWAY MAINTENANCE				
Channel dredging/cleaning	300 miles	20miles	15 miles	$1,347,784
Bridge/culvert clearing	1,000	2,400	2,200	$720,856
Erosion control projects	150	150	30	$234,989
INLET MAINTENANCE				
Storm sewer inlet inspection	18,000	18,000 2X	9,000 2X	$71,076
Storm sewer inlet cleaning	18,000	13,500 2X	6,750 2X	$236,920
Storm sewer inlet filter cleaning	178	8,544	8,544	$47,384
Wet debris dewatering	N/A	300	140	$94,768
STORM SEWER MAINTENANCE				
Storm sewer repair/installation	400 miles	unknown	2,800 feet	$289,151
Storm sewer cleaning	400 miles	unknown	13,500 feet	$142,151
Storm sewer inspection	400 miles	unknown	16 miles/yr	$191,076
Special projects	**N/A**	unknown	7 projects	$94,768
POND MAINTENANCE				
Water quality pond restoration	336	12	12	$762,089
Water quality/detention pond OMM	382	370	370	N/A
TOWN LAKE CLEANUP	N/A	[illegible]	170	$47,384

TABLE 8 - 5 E.
City of Austin
Stormwater Maintenance Plan
FY 1999.

Activity	Inventor	Estimated Need	Proposed Output	Proposed Budget
RESOURCE SERVICES				
Contract channel vegetation removal	300 miles	82 miles 3X	82 miles 3X	$850,000
Contract pond vegetation removal	400	400 ponds 3X	400 ponds 4X	$300,000
Complaint handling	N/A	2,050	2,050	$192,177
Storm sewer locating (utility coord)	N/A	3,100 loc./yr	3,100 loc./yr	$96,089
Maintenance scheduling/planning		N/A	N/A	$192,177
Street drainage repairs	unknown	unknown	unknown	$175,000
WATERWAY MAINTENANCE				
Channel dredging/cleaning	300 miles	20 miles	17 miles	$1,106,248
Bridge/culvert clearing	1,000	2,400	2,400	$582,832
Erosion control projects	150	150	30	$242,039
INLET MAINTENANCE				
Storm sewer inlet inspection	18,000	18,000 2X	18,000 2X	$73,208
Storm sewer inlet cleaning	18,000	13,500 2X	13,500 2X	$438,026
Storm sewer inlet filter cleaning	178	8,544	8,544	$48,805
Wet debris dewatering	N/A	300	150	$97,611
STORM SEWER MAINTENANCE				
Storm sewer repair/installation	400 miles	unknown	3,000 feet	$557,415
Storm sewer cleaning	400 miles	unknown	15,000 feet	$146,416
Storm sewer inspection	400 miles	unknown	20 miles/yr	$193,208
Special projects	**N/A**	unknown	8 projects	$97,611
POND MAINTENANCE				
Water quality pond restoration	385	15	15	$439,584
Water quality/detention pond OMM	438	423	423	N/A
TOWN LAKE CLEANUP	N/A	300	170	$48,805

TABLE 8 - 6.

Stormwater System OMM Costs in Denver, Colorado.

Channels with Earth Bottoms									
Years	**Chann Length**	**Channe Width**	**ROW Widt**	**Side Slopes**	**Slope/RO Material**	**# Mows/ Debris PU**	**Total Cost**	**$/Ft**	**$/Ft/Yr**
91-9	14,000	40	60	Flat	Grass	0/3	$14,189	$1.01	$0.25
86-9	7,750	25	150	4:1	Riprap/ Grass	5/3	$117,108	$15.11	$1.68
86-9	17,315	35	80	Flat	Boulder/ grass	6/30-40	$397,022	$22.93	$2.55
86-9	7,550	15	100	Flat	Grass	5/5	$110,990	$14.70	$1.63
89-9	10,300	20	40	Flat	Earth	0/3	$9,945	$0.97	$0.16
86-9	22,750	45	65	1:1/ Flat	Earth	0/3	$59,895	$2.63	$0.29
88-9	4,600	20	40	Flat	Earth	0/5	$7,374	$1.60	$0.23
Channels with Concrete Trickle Channels									
90-9	4,700	8	125	4:1	Grass	3/3	$15,759	$3.35	$0.67
86-9	4,550	6	50	2.5:1	Grass	3/3	$35,071	$7.71	$0.86
86-9	1,100	12	150	Flat	Grass	3/3	$11,387	$10.35	$1.15
86-9	4,150	6	100	4:1	Grass	3/5	$52,821	$12.73	$1.41
Dry Detention Systems with Grass Bottoms									
Years	**Channel Length**	**Sediment Removal**	**Area (Acres**		**Channel Material**	**# Mows/ Debris PU**	**Total Cost**	**$/Acre**	**$/Acre/Yr**
88-9	253	No	1.4		Concrete	4/4	$7,983	$5,702	$814.59
89-9	752	No	6.6		Concrete	3/3	$15,353	$2,326	$387.70
86-9	3,700	No	9.3		Earth	0/2	$9,076	$976	$108.43
86-9	3,085	Yes	15.5		Earth	0/2	$29,521	$1,905	$211.62

3.6. City of Bellevue, Washington

Bellevue's stormwater program has required the construction of facilities to minimize flooding and reduce pollutants since 1984. The City's Surface Water Management program maintains the stormwater management system . The system consists of a combination of 146 miles of open streams, ditches, and culvert, 290 miles of enclosed storm pipe, 14,000 catch basins and manholes, and 225 neighborhood and ten regional detention facilities. Program staff install, clean, repair, and inspect all components of the system and respond to emergency flooding situations.

In 1974 the City was one of the first local governments to implement a stormwater utility in 1974, providing a dedicated funding source for stormwater management and the OMM of the city's stormwater system. The budget for stormwater system OMM for the past three years is summarized below:

Year	Salary/Benefits	Supplies/Services	Capital	Total
1994	$ 636,171	$ 330,485	$ 247,621	$1,381,508
1995	$ 664,267	$ 383,043	$ 184,325	$1,422,232
1996	$ 661,801	$ 434,415	$ 67,280	$1,305,543

Table 8-7 summarizes Bellevue's stormwater OMM costs during 1994 and 1995. As part of its stormwater OMM planning process, City staff have been compiling cost information on specific BMPs. Annual OMM costs for some of these BMPs are summarized below:

Constructed wetland	Sediment removal	= $1,500
	Staff vegetation removal	= $ 530
	Contracted vegetation removal	= $ 975
	Total cost with overhead	= $3,846
Coalescing plate filters		= $ 832
API filters		= $ 512
Small wet vaults	Sediment removal	= $ 300

In addition to these costs, the city has installed several innovative stormwater treatment systems for which some OMM cost information is available, and has collected OMM data from nearby cities which are using other types of stormwater treatment BMPs. This information is summarized below:

A. Alum Injection System

Alum injection within stormsewer to precipitate stormwater pollutants has been used in Florida since 1986. In 1995, the City of Bellevue constructed an alum injection system to treat runoff from 5.4 acres of a new development at a cost of $92,000. The estimated annual OMM costs are:

Personnel (1 person, 12 hrs weekly @ $35/hr)	= $21,840
Aluminum sulfate (600 gallons/year)	= $ 1,000
Magnesium hydroxide (Buffer, 55 gal/yr)	= $ 240
pH probes (replacements, two/yr)	= $ 300
Electricity	= $ 504
Total annual OMM costs	$23,884

TABLE 8 - 7.
Stormwater System OMM Costs in Bellevue, Washington.

OMM ACTIVITY	1994 COMPLETED	1994 LABOR DAYS	1994 TOTAL COST	1995 COMPLETED	1995 LABOR DAYS	1995 TOTAL COST
Vacuum C/B, inlets	1,457	62.44	$21,586	2,134	101.06	$29,355
Vacuum Manholes	308	46.94	$15,877	436	58.69	$19,372
Vacuum Ditch	2653 ft	23.94	$7,244	3,582	40.63	$11,114
Vacuum Res. Pond	106	75.31	$26,690	41	30.25	$9,841
Jetrod Pipelines	29,620 ft	88.94	$31,196	38,750 ft	116.00	$39,413
Root Saw Pipelines	4,706 ft	45.63	13,863	5,356 ft	56.19	$16,064
Vacuum Oil Separator	8	4.63	$1,441	8	3.00	$965
Brush Res. Pond	43	163.56	$33,484	42	212.75	$36,350
Brush Region. Pond	7	34.00	$7,143	11	36.81	$7,942
Manually Clean Basins	4,897	165.63	$31,943	2,795	125.50	$24,117
Ditch Cleaning	9802 ft	63.25	$12,766	16,643 ft	96.63	$35,478
Repair CB Inlets, MH	249	141.56	$33,433	326	193.34	$41,263
Repair Pipelines	76 ft	20.56	$6,333	222	73.31	$32,420
Repair Res. Pond	62 hrs	33.25	$8,320	642 hrs	80.19	$17,331
Repair Region. Pond	532 hrs	66.44	$13,794	506 hrs	63.19	$14,316
Clean/repair Streams	53 hrs	93.69	$21,668	877 hrs	109.59	$26,247
Inspect Res. Pond	222	59.69	$11,597	251	56.38	$12,737
Inspect Oil Separators	70	8.25	$1,505	64	8.97	$1,897
Customer	362	81.38	$19,320	504	102.94	$24,205

B. Lakemont Filter System

Part of the stormwater system for the Lakemont Development, a single and multifamily residential development, included a BMP treatment train to serve 252.3 acres. The stormwater system consists of an underground wet vault, two filters, and a dry detention system. The total construction costs of this system in 1992 was $4.6 million. The estimated annual OMM costs are:

Personnel (2 people, total of 15 hrs/week @ $35/hr)	=$13,650
Phone for telemetry, flow gages	=$ 1,200
Electricity	=$ 720
Contracted maintenance of electrical controls	=$ 2,500
Filter media replacement	=$20,000
Vault sediment removal	=$ 1,500
Total	=$39,570

C. Compost Stormwater Filters

King County, Washington performed a cost study of these stormwater treatment systems (Table 8-8). Additionally, CSF Treatment Systems, Inc. which construct and maintain these systems, provided King County staff with the following estimates for two potential applications of this innovative BMP:

Assumptions:

Average annual OMM cost is based on a four year service contract with a 5% inflation factor. Maintenance includes two annual inspections and two minor OMM visits in the spring and early fall.

Disposal cost of $35 per cubic yard although often the material can be used for on-site landscaping or erosion control.

Cost estimates:

Filter 1 treats 12 acres of residential area with a peak discharge rate of 1.49 cfs. The filter area is 12' by 30' (360 sf) with a construction cost of $18,800 and an average annual OMM cost of $2,480.

Filter 2 treats 5 acres of commercial development with a peak discharge rate of 1.22 cfs. The filter area is 10' by 31' (310 sf) with a construction cost of $16,200 and an average annual OMM cost of $2,175.

3.7. Kitsap County, Washington

Like many local governments within the Puget Sound watershed, Kitsap County began requiring the treatment of stormwater in 1994. To provide a dedicated funding source for its stormwater management program, the county implemented a stormwater utility which generates $4 million through its user fees. Stormwater system OMM is a major component of the county's program, receiving 24% of the annual budget. Table 8-9 summarizes cost information on stormwater system OMM in Kitsap County. Costs are based on a labor cost of $25 per hour and a $55 per ton handling and disposal cost.

TABLE 8-8.

Stormwater Compost Filter System Costs (Compiled by King County Surface Water Management).

Tributary Area	Flow Rate (2 yr storm)	Constructio Cost	Cost per Tributary Acre	Annual OMM Cost
12 Acres, Residential	1.49 cfs	$18,800 Drop-In Filter	$1,570	$2,480
5 Acres, Commercial	1.22 cfs	$16,200 Drop-In Filter	$3,240	$2,175
50 Acres Residential	5.5 cfs	$47,900 Open Filter	$960	$5,600

TABLE 8 - 9.

Stormwater OMM Costs in Kitsap County, Washington.

CATCH BASIN SEDIMENT REMOVAL						
FACILITIE	# OMM/YR	PERSON HRS	PERSONNEL COSTS	CUBIC FEET SEDIMENT	DISPOSAL COSTS	ANNUAL $/FACILIT
549	549 (Once each)	284.3	$7,107.50	2,611.50	$9,797.75	$30.79
CONTROL STRUCTURE SEDIMENT REMOVAL						
49	49 (Once each)	147	$3,675.00	696	$2,587.44	$127.81
VEGETATION CONTROL						
$27.00	47 (1-4 each)	860	$2,150.00	$45.77/Operation	N/A	$79.63

4. FINANCING STORMWATER SYSTEM OPERATION, MAINTENANCE, AND MANAGEMENT

To provide the flood control, water quality protection, and other benefits for which stormwater systems are constructed, it is essential that maintenance and management be performed on a regular basis. As both the number of systems and the reliance upon them grows, the importance of stormwater system OMM grows accordingly. Unfortunately, experience throughout the country has shown that, for several reasons, stormwater system OMM is often neglected or, at best, performed only sporadically. This maintenance deficiency poses a serious threat to the safe and effective operation of the stormwater systems we have come to rely upon and to the health and safety of the people and water bodies the facilities are intended to protect.

While there are several reasons for this maintenance neglect, including lack of inspectors or institutional mechanisms, the primary cause is a lack of adequate maintenance funding. The problem of inadequate funding manifests itself in several ways, including insufficient staffing, inadequate equipment, lack of or inattentive facility inspections, and ineffective operation, maintenance, and management efforts.

Similarly, the problem of inadequate stormwater maintenance (or program) funding also has several causes. These include legal and regulatory constraints, a shortage of overall operating funds, poor stormwater program planning, and a lack of commitment by elected officials and by citizens. ***Unfortunately, stormwater management has always been "the orphan infrastructure" - only receiving public attention and funding in times of crisis*****.** At budget time, stormwater program funding seldom competes well against other community needs such as police protection, fire protection, ambulance service, etc. Accordingly, funding stormwater maintenance and management programs from traditional general fund sources has led to inadequate funding.

These causes signify an overall failure to recognize stormwater system OMM as a key component of any stormwater management program. ***The only way to solve this dilemma is through a comprehensive public information program which educates elected officials, citizens, and the private sector about the importance of stormwater management programs, proper stormwater system OMM, and the need for adequate funding***. Because of limitations on traditional general funding sources, the solution requires both commitment and creativity.

4.1. Public Financing of Stormwater OMM

A major policy issue facing local governments is whether they should assume responsibility for stormwater system OMM. Assumption of stormwater OMM may take the form of direct involvement by local government staff or by contracting with private maintenance services.

Where local governments already have assumed such maintenance, the lack of adequate funding has led to a seriously high level of facility maintenance default. This not only creates severe health and safety hazards for their residents and threatens the health of their water bodies, but it may also threaten the continuation of the overall stormwater management program. ***It is extremely difficult to generate the vital public support that a successful stormwater program requires if the local residents are surrounded by stormwater systems that are unsightly, unsafe, and ineffective***.

In addition, a local government may wish to assume the maintenance of all or some of the privately constructed stormwater systems within its borders. Traditionally, this has been the exception rather than the status quo. ***Most local governments prefer to require systems serving private land uses to be owned, operated, and maintained by private landowners or property owner associations. Unfortunately, history has shown that most private owners do an inadequate job of stormwater system OMM***. Consequently, as a last resort, more local governments are considering assumption of OMM responsibilities to restore and maintain existing systems which have already suffered continued neglect from owners or to avert anticipated defaults by potentially negligent owners. In either case, a lack of adequate funds will prevent the local government from assuming this maintenance, which in turn will only add to the growing list of unsightly, unsafe, and ineffective stormwater management systems within the community.

The problem of inadequate stormwater system OMM funding described above indicates that the traditional methods of public financing may either be ill-suited for this purpose or are not being used to their fullest extent. In response to these factors, four stormwater funding sources have been identified and are being used widely around the country. These funding sources, individually or in combination, offer a greater opportunity to provide an adequate source of funds to meet local government stormwater system OMM obligations. ***These four recommended funding sources are:***

- ***General tax revenues***
- ***Stormwater utility fees***
- ***Inspection or permit fees***
- ***Dedicated contributions***

Details about these four funding sources will be subsequently presented, along with suggested criteria for evaluating the suitability of each. Prior to a discussion of each one, however, it is important to note some fundamental aspects of public stormwater system OMM financing.

The success or failure of any proposed financing program which must receive public support and approval is often determined by the degree of information the public receives. For many reasons, the public is generally protective of its dollars and initially suspicious of any new public program which proposes to spend them. Often, this suspicion is beneficial, for it helps promote sound fiscal planning and spending programs.

However, where this suspicion is unwarranted and cannot be overcome, it may also prevent a valuable and fiscally sound program form advancing beyond the proposal stage. Therefore, ***the value of a comprehensive public information program can not be overemphasized. Such a program must explain the basis, purpose, and details of the financing proposal and must convince the public and their elected officials that it is both necessary to implement and beneficial to their interests***. Experience has shown that citizens and elected officials don't mind spending money if they know exactly what the money will be used for and what benefits the expenditures will provide to the community.

All successful stormwater management maintenance (or program) funding programs should possess certain fundamental elements or characteristics. These include:

- ***Be based upon a stable source of consistent funds***. Proper stormwater system OMM must be continually and consistently performed on a regularly scheduled basis. This requires a long term commitment of personnel, equipment, and materials. As a result, the funds to support this commitment must be based upon a stable, secure, and reliable source.

- ***Be compatible with the local organizational structure***. The overall effectiveness of a stormwater OMM program is based to a large extent upon the efficiency of its funding program. The most efficient funding program is that which is most compatible with the organizational structure of the managing department, agency, or authority. Wherever possible, the funding program should use the billing, collection, and bookkeeping operations of an existing public system.

- ***Include provisions for the four essential operations - Program Administration, Accounting and Budgeting, Revenue Management, and Information Management****.* Program Administration is needed to insure the effective and efficient operation of the overall program. Accounting and Budgeting procedures are needed to accurately track operations and determine required funding levels. This may include the use of detailed work orders and time sheets by maintenance and inspection personnel and their supervisors. Revenue Management must insure a secure and reliable source of program funds to meet expenses and oversee their expenditure. Information Management must provide all of the above with comprehensive and accurate data upon which operational decisions can be based. It must also foster program understanding and support by providing government leaders and the public with timely information, explanations, and answers.

- ***Be based upon an equitable, understandable, and defensible fee or rate structure****.* Stormwater OMM funding programs may require complex procedures and operations in order to provide adequate funding levels. However, to obtain public acceptance and support, the program's fees or rates must be based upon a formula or method that can be readily explained to and understood by the public. The fees or rates must be perceived as being both reasonable and equitable and based upon accurate data and sound decisions.

- ***Be continually reviewed and updated****.* Program costs, revenues, and responsibilities must be regularly evaluated and adjusted as needed to maintain maximum cost effectiveness. The do this, the program must possess a flexibility of approach which will allow it to quickly respond to such changes. This is especially true when a large storm occurs and OMM needs are increased significantly.

- ***Be consistent with applicable state laws and regulations****.* The final details of a specific public stormwater OMM financing program will depend to a great extent upon the general authorities and requirements established in state law or regulations. Prior to the adoption of any financing program, the local government's general counsel should review all details of the program to assure it is compatible with state law.

4.1.1. General Tax Revenues

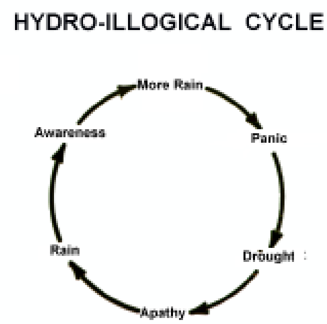
Around the nation, t***he general tax fund is the most commonly used source of funding for stormwater programs and stormwater system OMM***. General tax revenues are an obvious source of funding since the purpose of local government taxes is to fund activities necessary to provide for the community's health, safety, and welfare through the implementation of a number of social, economic, recreational, and environmental programs. Accordingly, since properly functioning stormwater systems provide public heath, safety, and environmental benefits, and since neglect of stormwater system OMM can create serious health, safety, and environmental hazards, the use of general tax revenues to provide for the maintenance of stormwater systems can be construed as being consistent with this purpose.

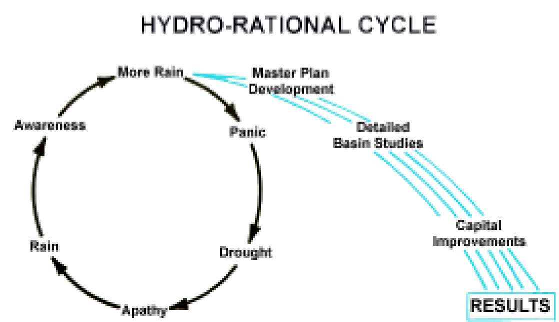
However obvious, ***general tax revenues may also be the least suitable source of stormwater program or maintenance funding***. As the name implies, "general" tax revenues originate at a number of sources and are used to finance an equally diverse number of public programs, including police and fire protection, civil and criminal courts, social and economic support programs, roadways, utilities, and recreational activities and facilities. This combination of broad base and use creates two distinct problems which must be overcome if general tax funds are to be used to support public OMM of stormwater systems.

First, with such a broad base, it may be difficult to justify the expenditure of general funds to maintain a stormwater system that will only benefit a portion of the taxpaying community. Second, with an equally broad use, ***stormwater programs and maintenance must compete against a large number of other vital public programs for a very limited number of tax dollars***. This is one reason why so many stormwater programs are inadequately funded and why so many stormwater systems are improperly operated and maintained. This problem has been compounded in recent years by tax caps and the public's general opposition to new or higher taxes.

Elected officials have discretionary authority in allocating general tax revenues through the annual budget process. However, both a government' s responsibilities and its political realities tend to define how these funds are actually spent. Mandatory services such as police and fire protection must receive priority over more discretionary budget items such as stormwater system OMM. Therefore, to win use of general tax funds to finance stormwater system OMM, it must be demonstrated to the public and to elected officials that this activity has greater importance than other discretionary budget items.

The success of this effort will depend upon many factors, including the overall costs and community benefits of the maintenance program, the severity and extent of the maintenance neglect problems, and the effectiveness of the methods used to inform and educate the public and their elected officials. ***Experience has shown that this effort is often successful after a recent "crisis" such as a major flood or contamination of an important community water body. These calamities present an opportunity to gain public support and to prevent future disasters. They are an excellent time to break the "hydro-illogical cycle" and implement the "hydro-rational cycle"***.





4.1.2. Stormwater Utility Fees

The unreliability of using general tax funds to finance stormwater programs or stormwater system OMM has led many communities around the country to implement either a stormwater utility fee or a stormwater special assessment. The use of utility charges to finance publicly owned water and sewer systems began in the early 1900s and, today, provides a stable source of funds for local utility authorities and agencies around the nation. In recent years, with the adoption of tax limitations, utility charges and special assessments have become increasingly popular as local governments attempt to maintain an adequate level of public services in the face of limits on expenditure growth.

The concept of a utility charge to publicly finance stormwater system OMM is a sound one in several respects. Unlike general tax revenues, utility charges are not subject to state "tax cap" limitations. The public is used to utility charges because of the precedent set by water and sewer charges. Most importantly, a more direct relationship between costs and benefits of stormwater system OMM can be demonstrated than through the general assessment of local taxes. Finally, similar to general tax revenues, the stormwater utility charge can be used to publicly finance the maintenance of both new and established stormwater systems.

A variation of a city or county-wide stormwater utility fee is the establishment of a stormwater benefit area in which all property owners pay a special assessment charge. The charge generally is assessed on a per acre basis to fund construction and OMM of stormwater facilities within the benefited area. Additionally, if different land uses within the benefit area receive substantially different levels of stormwater benefits, the assessment of per acre fees from subarea to subarea should vary in proportion to the benefits received. The boundaries of the benefit area should be based on the contribution of runoff to the stormwater system. This may include the tributary drainage area for a single stormwater system, especially if it is a regional facility, or more commonly, for an entire network of facilities within a watershed or subwatershed.

Special assessment charges within a benefit area should meet the following criteria:

- Fees should not exceed the amount of the benefit received by any particular property.
- Fees should be properly allocated to the benefited properties.
- Property owners should have an opportunity to comment, or even vote, on how the assessments are allocated to their properties.

Whether for a stormwater utility fee or a special assessment fee, an important need is to establish a relationship between the fee and the benefits received. Unlike charges for water or sewer, a readily measured commodity is not delivered to the stormwater utility or benefit area customer. To a lesser extent, the service provided by stormwater system OMM is not as readily perceived or quantified as the service provide by a wastewater system which continually disposes of sanitary wastes from homes or businesses. As a result, the services provided to, and the benefits received by, the utility customer or special benefit property owner must be more broadly defined if an acceptable and equitable utility charge or special assessment is to be developed. ***The goal is to show that assessed fees are used to cover costs of stormwater system OMM or other stormwater services benefiting each property and that the benefits to each property are at least equal in value to the assessment fee***. Constitutional standards require that property owner benefits be special benefits which are generally not shared by the community as a whole.

The utility rate structure for a stormwater facility maintenance district should be based on several considerations. The most fundamental of these is the concept of payment based upon contribution to the need for the maintenance rather that the benefits provided by it. For example, a typical stormwater system OMM charge may be based upon the size of the property contributing runoff to the facility. This rate may be refined to reflect the percentage of impervious surfaces on the property, the runoff potential of the remaining pervious areas, the type of land use, and other factors affecting the rate, volume, or pollutant loading of stormwater. For example, a one acre property containing a single family residence with 20 percent impervious area would pay proportionally less than a similarly sized industrial property with 80 percent impervious cover for the OMM of the stormwater system to which these lands contributes runoff .

While a certain degree of complexity may be required to equitably distribute OMM costs throughout the community or special district, the rate structure should remain as simple as possible. This simplicity will help make the rate structure more understandable to the rate payer and, as a result, more acceptable. The rate structure should also retain a degree of flexibility to accommodate changes in program revenues, expenses, and responsibilities.

The rate structure also must reflect the costs of providing the essential stormwater program elements listed in pages 8-21 and 8-22. These administrative and support costs are estimated to range from 10 to 25 percent of total program costs.

If a local government does not wish to own, maintain, and operate private stormwater systems, stormwater utility fees can provide an economic incentive to increase the likelihood that the private property owners will actually conduct OMM activities. Several local stormwater utilities provide "credits" if a property or subdivision has an on-site stormwater management system which is being maintained properly. An administrative problem with this system that must be addressed is how to assure that the private systems are being maintained properly. Some local governments have established Stormwater Operating Permits which require an annual inspection by staff or certification by a private inspector that the facility is being maintained and is operating as constructed. Since state and local government stormwater programs often have too few inspectors, the programs in Delaware and Florida have implemented training and certification programs for public and private sector personnel who wish to conduct inspections.

4.1.3. Inspection or Permit Fees

Similar to utility fees or special assessments, the use of inspection or permit fees to publicly finance stormwater system OMM represents a relatively new application of an established component of government revenues. In many states, local governments have the general authority to establish fees and other charges to pay for the operational expense of various programs and services. Often, these fees are associated with the issuance of a permit, such as a building permit, clearing or grading permit, stormwater permit, or sewer connection permit. Alternatively, these fees may be associated with building or stormwater program requirements for inspections.

Implementing a successful stormwater system OMM program funded entirely or partially by inspection or permit fees requires the establishment of two primary relationships. First, the permit program itself must be directly related in some manner to stormwater systems and, preferably, their operation and maintenance. For example, the use of fees from a sanitary sewer connection permit program to finance stormwater system OMM may not be feasible, permissible, or acceptable to the public. However, the use of fees from a storm sewer connection program may be. Other potentially feasible permit fees include those for a local construction permit, stormwater permit, or stormwater discharge permit. Inspection fees can be required when the local government's stormwater program requires a periodic inspection of private stormwater systems. The public inspections can determine whether the owner is maintaining the facility properly. If not, they can help identify what OMM activities are needed and notify the owner. A permit program based upon fees for annual inspections, such as a stormwater discharge or stormwater operating permit, can provide a continuing source of funds. However, many permit or inspection fees are a one time charge, typically when the facility is first constructed. These are not a good funding source for continuing stormwater system OMM.

Second, a relationship should be established, if possible, between the payer of the inspection or permit fee and the use of the fee itself. For stormwater inspection fees, this relationship is relatively easy to establish. For permit fees, it is recommended that the fees be placed into dedicated accounts. To demonstrate that the fees are being used for the OMM of specific facilities, it is recommended that computer data bases be established to track facility maintenance activities and costs. This data base will also allow the stormwater program to more accurately estimate future resources and funding needed to adequately maintain stormwater systems. The more directly either of the above relationships can be established, the greater the chances of public acceptance.

Similar to utility charges, inspection and permit fees should reflect the concept of payment based upon contribution to the need for facility OMM rather than the benefits provided by it. For example, factors to consider in establishing a stormwater construction permit fee might include the size of the proposed facility, its contributing drainage area, the number of BMPs or structures, and whether it is for stormwater quantity control, stormwater quality control, or both. Therefore, a relatively small facility serving a residential area and intended only for quality control would be charged a proportionately lower permit fee than a larger facility providing both quantity and quality control to a commercial area. The same factors could be considered when establishing an inspection fee along with the number of inspections, time to conduct inspections, and time to travel to the site.

As with stormwater utility fees, permit or inspection fees need to be as simple as possible but still provide for an equitable distribution of costs. The fee schedule should also provide flexibility to accommodate changes in program revenues, expenses, and responsibilities. It also needs to reflect the costs of program administration, accounting and budgeting, and revenue and information management.

4.1.4. Dedicated Contributions

The use of dedicated contributions from land developers to finance public maintenance of stormwater systems represents an extension of an established procedure in a new direction. Under this program, the local government assumes the OMM of a stormwater system constructed as part of a private development. The actual OMM can be provided either by local government staff or through contract with a private maintenance service. ***All or a portion of the required funding for the OMM is obtained through a one-time contribution by the land developer to a dedicated account which is controlled by the local government. Often the developer is responsible for OMM during a "warranty period", frequently the first two years***.

The amount of contribution to the dedicated account could be based upon several factors including:

1. The type of stormwater BMP and the anticipated OMM activities.
2. The total number of years in which facility OMM would be provided.
3. The present annual maintenance, administrative, insurance, and support costs.

4. The anticipated annual increase in present costs due to inflation, equipment depreciation and replacement, increases in labor and insurance rates, rising disposal costs, and other factors.
5. The anticipated interest earned by the dedicated contribution.
6. The percentage, if any, of cost sharing between the developer and the local government.

The type of stormwater BMP will determine the frequency and types of needed OMM operations. Unfortunately, an extensive data base on this information is not available. However, the information presented earlier in this chapter can help to develop cost estimates of stormwater facility OMM. Administrative and support function costs are estimated to range from 10 to 25 percent of total program costs. An annual cost of 2 percent of the dedicated funds may be required to cover the administrative costs of the dedicated accounts themselves. This information can be used to help estimate the present annual OMM, administrative, insurance, and support costs.

The total number of years for which OMM will be provided will vary with the policies of each local stormwater program. Often the dedicated contribution is based on public OMM for 25 years, after which stormwater OMM costs are financed through either the local governments general tax revenues or stormwater utility fees.

The Township of West Windsor, New Jersey has established a Dedicated Contribution Program and will be used as an example for calculating the developer's contribution. The program is based upon the Township providing 25 years of OMM after which the stormwater OMM will be financed through the Township's general tax revenues. Participating developers are required to furnish 75 percent of the estimated annual stormwater system OMM costs in the form of a one-time payment. The amount of this payment is calculated for each facility through the use of a standardized Developer Contribution Worksheet (Table 8-10).

In the West Windsor program, annual OMM costs are based upon the performance of four major maintenance tasks by Township personnel. These tasks are grass mowing; landscape maintenance; general maintenance, which includes trash and debris removal and erosion repair; and periodic sediment removal and bottom restoration. Grass mowing is estimated at the rate of one acre per hour. Other required tasks are estimated based upon an hourly, yearly, or per task basis. Appropriate factors are used to reflect infrequent OMM tasks such as sediment removal and bottom restoration. Annual liability insurance costs are also estimated and combined with the estimated annual costs of the four major maintenance tasks to produce a total first-year OMM cost for the facility. This value is multiplied by an appropriate Present Worth Factor and then by 0.75 to determine the actual amount of the developer's dedicated contribution. This Present Worth Factor is based upon an average annual interest rate on the dedicated funds of 8 percent and an average annual cost increase of 6 percent over the 25 year OMM period.

The use of dedicated contributions to finance stormwater OMM has many advantages. First and foremost, they provide a secure, dedicated funding source for future stormwater OMM activities. Unlike general tax revenues, contributions to dedicated accounts are not subject to state tax cap limits. A disadvantage is that dedicated contributions are only applicable to new stormwater systems. The use of these funds and the activities they pay for need to be closely tracked. This is fairly easily done through account and expense records. This information can be used to demonstrate a direct relationship between the contributed funds and their use for facility OMM.

Equally important, this type of a data base can help the local government to better estimate the OMM costs of future new facilities and to estimate funding needs for OMM of older stormwater systems. To minimize overall administrative costs, it is recommended that a single dedicated account be established for all developer contributions.

TABLE 8 - 10.

Sample Worksheet for Calculating Dedicated Contribution To Stormwater Management System OMM.

NAME OF DEVELOPMENT: ____
LOCATION: ____
TYPE OF STORMWATER SYSTEM: ____
NUMBER OF ACRES OF STORMWATER SYSTEM: ___________________________
NUMBER OF ACRES CONTRIBUTING TO THE SYSTEM: ______________________

1. MOWING

A. Rate per hour for labor and equipment =$____________
B. Base number of hours for labor and equipment for mobilization and mowing up to one acre: ___________
C. Number of hours for mowing additional area (based on one hour per acre) ___________
D. Hours needed for mowing = B + C =_____________
E. Cost per mowing = A X D =$____________
F. Number of mowings per year: ___________
G. Annual mowing cost = E X F =$____________
H. Materials cost =$____________
I. Total cost = G + H =$____________

2. LANDSCAPE MAINTENANCE

A. Rate per hour for labor and equipment =$____________
B. Number of hours of required landscape maintenance per year: ___________
C. Annual landscape maint. cost = A X B =$____________
D. Materials cost =$____________
E. Total cost = C + D =$____________

3. GENERAL MAINTENANCE

A. Rate per hour for labor and equipment =$____________
B. Number of required hours of trash and debris removal per occurrence: ___________
C. Number of required hours of erosion and sediment repair per occurrence: ___________
D. Number of required hours of sediment removal per occurrence: ___________
E. Number of required hours of other specific maintenance per occurrence: ___________
F. Cost per occurrence = A X (B + C+ D+ E) =$____________
G. Number of occurrence per year: ___________
H. Total cost = F X G =$____________

4. INSURANCE

A. Annual insurance cost =$____________

TOTAL FIRST YEAR COST

1. MOWING (1.I.) =$____________
2. LANDSCAPE MAINTENANCE (2.E.) =$____________
3. GENERAL MAINTENANCE (3.H.) =$____________
4. INSURANCE (4.A.) =$____________

TOTAL FIRST YEAR MAINTENANCE COST =$____________

CALCULATION OF DEVELOPER CONTRIBUTION

A. TOTAL FIRST YEAR COST =$____________
B. FOR 25 YEARS = x 19.79
C. TOTAL REQUIRED AMOUNT = A X B =$____________
D. DEVELOPER CONTRIBUTION PERCENTAGE = X 0.75
E. DEVELOPER CONTRIBUTION = C X D =$____________

Chapter 9
Disposal of Stormwater Sediments

1. OVERVIEW

Assuring that stormwater management systems will provide their desired benefits is no easy task. There are many challenges to overcome. The stormwater management system must be properly designed and constructed. The stormwater program's institutional framework must assure that periodic inspections occur during and after construction of the stormwater system, and that an operation and maintenance entity is clearly identified and legally responsible for the long term operation, maintenance, and management of the stormwater system.

Once these hurdles are cleared, new challenges arise. ***A growing concern, as more and more stormwater treatment systems are constructed, is how should the sediments that accumulate in them be disposed***. The stormwater pollutants that accumulate in the sediments are highly variable, but they often include several contaminants such as heavy metals, petroleum hydrocarbons, and other organic compounds, such as pesticides or solvents, which may be considered hazardous wastes.

This chapter will discuss the applicability of federal and state solid and hazardous waste laws which may affect the proper disposal of stormwater sediments. It will also summarize data on stormwater sediments from the few studies which have been conducted to characterize them. Recommendations will be provided on whether stormwater sediments need to be characterized before disposal and what types of tests need to be conducted. Finally, recommendations will be made on how stormwater sediments should be safely disposed.

1.1. Intended Readers

This chapter is intended primarily for:

- **Public Officials and Regulatory Personnel**, who need to be aware of the applicability of federal and state regulations which may apply to the disposal of stormwater sediments.

- **System Owners or Operators**, who need to know how to properly test and dispose of sediments which accumulate in their stormwater systems.

2. POTENTIALLY APPLICABLE LAWS AND REGULATIONS

Stormwater pollutants include a wide variety of substances that are deposited on pervious and impervious surfaces and then transported by the next rainfall. Additionally, especially in older urbanized areas, there are often connections to the stormwater system which should go to the sanitary sewer system. Consequently, a wide variety of contaminants that may be classified as hazardous or toxic may enter stormwater management systems. These contaminants include heavy metals, petroleum hydrocarbons, pesticides, and a wide variety of organic chemicals. ***Consequently, several federal and state laws and regulations may apply to the disposal of sediments which accumulate in stormwater systems or which are captured by street sweepers***.

Unfortunately, few state or local governments have established clear policies, guidance, or rules on disposal of stormwater sediments or the applicability of federal, state, or local laws and rules. Seldom do current laws, ordinances, rules, or guidelines governing solid waste handling and disposal address waste removed from stormwater systems. This ambiguity makes it difficult for public and private operators to comply with relevant laws and regulations in their stormwater management system maintenance programs. As a result of these unanswered handling and disposal questions, many stormwater management agencies have been discouraged from performing routine maintenance of stormwater systems.

This section will discuss laws and regulations that may be potentially applicable to stormwater system sediment disposal.

2.1. Federal Laws and Regulations

<u>A. Resource Conservation and Recovery Act of 1976 (RCRA)</u>

RCRA requires generators of hazardous wastes to monitor and manage them in accordance with specified procedures. A solid waste may be considered a hazardous waste if it contains materials which are specifically listed in Sections 261.31 through 261.33 of 40 CFR or because it possesses any of four hazardous characteristics (ignitability, corrosivity, reactivity, or toxicity). In nearly all cases concerning stormwater sediments, the reason that they could be classified as hazardous wastes is because they contain listed chemicals rather than because the sediments are hazardous by characteristic. However, ***it is possible for stormwater sediments to be classified hazardous wastes because they exhibit toxicity. Stormwater sediments would exhibit toxicity if, using the Toxicity Characteristic Leaching Procedure (TCLP), the extract contains contaminant concentrations which exceed the limits listed in Table 1 of Section 261.24 of 40 CFR*** (See Table 9-3 for a partial listing of these limits).

Key aspects of RCRA and its implementing regulations which may affect stormwater sediment disposal include (Jones et. al., 1995):

- *The Mixture Rule*. RCRA regulations include lists of a number of chemicals and their by-products that are considered hazardous wastes when used and discarded (see Sections 261.31 through 261.33 of 40 CFR). Under the mixture rule, a mixture of any solid waste (including dirt) and the listed waste is considered by regulation to be a hazardous waste. Even small concentrations of a listed waste can render large volumes of material hazardous waste.

- *The Derived-From Rule*. If solid waste is considered hazardous waste, even if by operation of the mixture rule, then any residue from the treatment, storage, or disposal of the hazardous waste is also considered to be hazardous waste.

- *The Contained-In Policy*. Under existing EPA policy, environmental media, such as soil, water, or debris, that contain a hazardous waste must be handled as a hazardous waste.

- *The Nature of the Source Material.* Simply because a chemical listed in RCRA rules is detected in stormwater sediments does not make the sediments hazardous waste, even after discard. For example, if a spent halogenated solvent listed as hazardous waste is detected in stormwater sediments, the sediments would be hazardous waste under the mixture rule only if the source of the spent solvent contained more than ten percent of that solvent by volume.

The Mixture and Derived-From rules do not apply to stormwater sediments until they are removed from the BMP. Only then are the sediments considered to be discarded. It is the

Contained-In Policy, rather than the mixture or derived-from rules, that is most likely to bring stormwater sediments within the scope of RCRA regulations. A de minimis exception to the contained-in policy can be used on a site-specific basis. EPA must then demonstrate that contaminated media contain hazardous waste before applying RCRA requirements. It is likely that EPA will apply the Contained-In policy to stormwater sediments, but the policy, as applied to contaminated media, has not been adopted as a rule.

B. Federal Water Pollution Control Act - NPDES Regulations

Discharges of pollutants to waters of the United States or to certain master stormwater systems owned or operated by local government may require a NPDES permit from EPA or the state water quality agency. For example, these regulations would apply to discharges of vactor truck water to storm sewers.

2.2. State Laws and Regulations

The owner, operator, or responsible maintenance entity of a stormwater management system should request the stormwater permitting or program agency to provide information about the potential applicability of state or local laws and regulations to the disposal of stormwater system sediments. This request may not bring a quick or simple answer depending on how long the stormwater program has been in operation and whether this issue has been addressed.

The laws and regulations in different states and local governments are going to vary considerably. Be sure to consult your appropriate local or state agency. The following discussion will summarize how laws and rules in two states - Washington and Florida - address the issue of stormwater sediment disposal.

A. Washington State

The *Washington State Solid Waste Management Act (R.C.W. 70.95)* classifies solids collected from stormwater systems and street cleaning as solid wastes. The Act defines these wastes as street waste solids. Such wastes must be stored and handled according to relevant solid waste regulations.

One of the highest priorities of the Act is to encourage waste recycling over landfill disposal. Government agencies can frequently use street waste solids for fill or other uses permitted by local health departments. To be designated as street waste solids in Washington state, and avoid handling as a hazardous waste, contaminant concentrations in solids must not exceed the levels presented in Table 9-1.

If garbage, refuse, and other contaminants are removed from stormwater facility sediments, they may not even require handling as solid waste. Such solids must consist only of soil, sand, gravel, or sediment. However, these materials should not be used as residential topsoil or in locations where they could have contact with wetlands, surface waters, ground water, wells, or utility trenches.

The *Washington State Model Toxics Control Act (MTCA)* establishes waste contamination thresholds, above which materials must be handled as hazardous waste (see Table 9-2). ***The hazardous waste threshold of 200 milligrams per kilogram (mg/kg) total petroleum hydrocarbons (TPH) is particularly relevant to disposal of stormwater sediments***. Wastewater treatment plants typically set maximum influent pollutant concentration levels (see Table 9-2). These pretreatment standards are established to avoid disruption to plant operations by toxic substances and impacts to receiving waters by contaminants that the plant cannot adequately remove. ***The applicability of***

TABLE 9-1. Maximum Contamination Limits for Street Waste Solids[1] in Washington State

Contaminant	Analytic Method	Max. Concentration (ppm)[2]
Heavy fuel hydrocarbons (C_{24} -C_{30})	EPA WTPH 418.1	2000
Diesel (C_{12}-C_{24})	EPA WTPH-D	500
Gasoline (C_6-C_{12})	EPA WTPH-G	250
Benzene	EPA 8020	0.5
Ethylbenzene	EPA 8020	20
Toluene	EPA 8020	40
Xylenes (total)	EPA 8020	20

[1]Solids collected from stormwater facility and street cleaning [2]ppm = parts per million

TABLE 9-2. Standards for Disposal of Wastes under TCLP[1], MTCA[2], and Pretreatment Standards[3] in Washington State.

Type of Waste/ Contaminant	Legal Standard	Maximum Concentration Limits
Solids		
Lead	TCLP[1]	5.0 mg/L = 100 mg/kg
TPH	MTCA[2]	200 mg/kg
Vactor Water		
Copper (daily average)	Pretreatment standards[3]	2.00, 3.00 mg/L
Copper (grab maximum)	Pretreatment standards[3]	8.00 mg/L
Lead (daily average)	Pretreatment standards[3]	1.50, 2.00, 3.00 mg/L
Lead (grab maximum)	Pretreatment standards[3]	4.00 mg/L
Zinc (daily average)	Pretreatment standards[3]	1.50, 4.00, 5.00 mg/L
Zinc (grab maximum)	Pretreatment standards[3]	10.00 mg/L

[1] Toxic Characteristic Leaching Procedure (US Environmental Protection Agency)
[2] Model Toxics Control Act (enacted in Washington state)
[3] Pretreatment standards are from Lynnwood, Everett, and Seattle, WA.

TABLE 9-3. Florida Criteria for Clean Soils, Rule 62-770, F.A.C.

Parameter	Max. Conc. TCLP (mg/l)	Max. Conc. (mg/kg)(1)	Parameter	Max. Conc. (mg/kg)(1)	Parameter	Max. Conc. (mg/kg)(1)
Arsenic	5	0.8	Benzene	1.1	PAHs	2300
Barium	100	87000	Toluene	300	TRPHs	370
Cadmium	1	640	Xylenes	290	MTBE	350
Chromium	5	290	Pyrene	2200	Anthracene	19000
Lead	5	500	Fluorene	2100	Naphthalene	1000
Mercury	0.2	3.7	Chrysene	140	Phenanthrene	1900
Selenium	1	390	Dibenzo(a,h)-anthracene	0.1	Benzo(a)pyrene	0.1
Silver	5	390			Benzo(a)anthracene	1.4

(1) Values based on residential land use assumptions.

these pretreatment standards is especially relevant to discharges of water collected by vactor trucks.

B. State of Florida

Florida was the first state in the country to require the use of best management practices to treat stormwater from all new development. The adoption of Section 17-4.248, Florida Administrative Code (F.A.C.), in 1979, and the subsequent adoption of Chapter 17-25, F.A.C. (now 62-25), in 1981, along with the incorporation of stormwater treatment requirements into the Management and Storage of Surface Waters (MSSW) regulations of the water management districts has led to the construction of tens of thousands of BMPs throughout the state. These stormwater treatment practices are an essential component of the state's management programs to protect, maintain, or restore the quality of Florida's surface and ground waters.

In response to numerous questions concerning proper procedures for disposing of sediments which accumulate in stormwater BMPs, the Stormwater/Nonpoint Source Management Section at the Florida Department of Environmental Regulation published Guidelines for Sampling, Analyzing, and Disposing of Stormwater Sediments in November 1992. The guidelines outline biological, chemical, and toxicity leaching testing procedures which could be used to determine the characteristics of the stormwater sediments. The paper also outlines recommendations for disposal of the sediments after they have been characterized.

In developing these guidelines, staff coordinated with the staff in the Divisions of Waste Management and Water Facilities to assure compatibility with the rules and policies imposed by other Department programs. A major policy issue concerned which program's criteria to apply to stormwater sediments. Rules and criteria used by the following programs were reviewed and analyzed for applicability to disposal of stormwater sediments:

- Domestic wastewater residuals
- Solid waste management facilities
- Compost made from solid waste
- Soil thermal treatment facilities
- Interim soil cleanup goals
- Sediment quality assessment guidelines

Ultimately, the stormwater sediment disposal recommendations were based on the Waste Clean Up Program's "Clean Soil Criteria" found in Chapter 62-775, F.A.C. (Table 9-3).

The Florida Department of Environmental Protection currently is reevaluating the applicability of the limits of the various above programs to stormwater sediments. ***One of the major problems is the lack of consistency between programs and the apparent conflict between the values for allowable concentrations of metals in materials to be land-applied. One reason for the differences in allowable concentrations is that the assumed risk level varies depending on the program***. The Clean Soils Criteria were developed using a risk level of 1×10^{-6}. The Residuals criteria also are based on a 1×10^{-6} incremental cancer risk goal for carcinogens, but use a 1×10^{-4} incremental cancer risk for non-carcinogens. EPA's proposed Bright Line concentrations were developed using a 1×10^{-3} risk factor.

3. CHARACTERISTICS OF STORMWATER SEDIMENTS AND WASTES

This section will present a summary of data, primarily from Washington and Florida, on the concentrations of different contaminants typically found in stormwater sediments and vactor water.

Preliminary studies have indicated that vactor wastes can surpass dangerous waste levels for several metals and petroleum hydrocarbons. ***A study by Herrera Environmental Consultants (1991) found that vactor truck sediments generally exceeded the Washington Model Toxics Control Act criteria for polyaromatic hydrocarbons (PAHs) and TPH. Concentrations of the most often detected compounds were greater in wastes from industrial areas than from residential and commercial areas***.

Disposal of decant water, the liquid fraction of storm facility wastes removed by vactor trucks, also poses risks to water quality. Decant water has the potential to carry solids, metals, toluene, xylenes, and volatile and semi-volatile compounds. Total suspended solids (TSS) are a principal pollutant in street waste liquids. Many contaminants, particularly metals, bind to fine particles, organic material, and clay particles. Total Kjedahl nitrogen is associated with particles in the 250 to 2000 micron size range. Total phosphorus and nitrate-nitrogen bind to particles smaller than 100 microns, but most nitrate-nitrogen is in solution. Liquids can also contain large numbers of fecal coliform bacteria. Toluene, xylene, and ethylbenzene are among the most frequently detected organic compounds in decant water. Table 9-4 presents pollutant ranges for street waste solids and liquids, as reported by Serdar (1993). Illicit dumping and property owner practices can greatly increase contaminant concentrations in stormwater management facilities.

TABLE 9-5. Ranges of Pollutant Contamination in Washington State Catch Basin and Vactor Wastes, by Land Use (from Jacobson, 1993).

Type of Waste/	Residential	Commercial	Industrial	Highway

Vactor truck crew removing stormwater sediments and liquids from a catch basin.

TABLE 9-4. Ranges of Toxics and Other Materials Concentrations in Street Waste Solids and Liquids (from Serdar, 1993)

Substance	Concentration Ranges in Solids	Concentration Ranges in Liquids
Solids	61 - 85%	-
Gravel fraction	1 - 33%	-
Sand fraction	57 - 90%	-
Silt fraction	4 - 28%	-
Clay fraction	0 - 3%	-
Fecal coliforms	-	400 - 9000 MPN/100 mL
TSS	-	265 - 111,000 mg/L
Settleable solids	-	2 - 234 mL/L/hour
Dissolved solids (total)	-	95 - 550 mg/L
Arsenic	Undetected - 24 mg/kg	0.030 - 1.240 mg/L
Cadmium	0.5 - 1.8 mg/kg	-
Chromium	19 - 241 mg/kg	0.013 - 1.81 mg/L
Copper	18 - 560 mg/kg	0.081 - 7.6 mg/L
Lead	24 - 194 mg/kg	0.255 - 13 mg/L
Mercury	0.04 - 0.16 mg/kg	Undetected-0.022 mg/L
Nickel	33 - 86 mg/kg	-
Zinc	80 - 558 mg/kg	0.401 - 18 mg/L
TPH	0.040 - 4.600 mg/kg	-
PAHs (total)	0.890 - 146 mg/kg	-
Toluene	-	0.096 - 0.180 mg/L
Xylenes (total)	-	0.020 - 0.360 mg/L
Phenol	-	0.002 - 0.075 mg/L

A paper produced by the Center for Urban Water Resources Management at the University of Washington collected and summarized data from Washington state research on catch basin and vactor waste contamination (Jacobson, 1993). The objective of the study was to determine any correlations between land uses and pollutant concentrations in storm facility wastes. Results of the study are presented in Tables 9-5 and 9-6.

Contamination levels in sediment wastes and vactor liquids from residential and commercial areas were quite similar. Solids and vactor liquids from industrial areas were generally significantly more polluted than those of residential and commercial areas. However, several commercial and industrial results overlapped, indicating that these two land uses sometimes have similar pollution potential.

The Jacobson study concluded that stormwater system solids must be disposed of with caution because of high TPH concentrations. Similar results were found in a 1995 analysis of vactor sediments that had been stockpiled at a maintenance yard in Bellevue, Washington. Although such wastes are probably not so contaminated that they require hazardous waste landfilling, they are too polluted for some standard landfills.

Although copper and lead concentrations in vactor water from residential and commercial areas were not high enough to cause concern, zinc frequently exceeded standards. ***Vactor***

Contaminant	(ppm)[1]	(ppm)[1]	(ppm)[1]	(ppm)[1]
Catch Basin Solids				
Copper	20-126	18-117	165-456	-
Lead	101-636	95-1726	230-500	-
Zinc	174-336	165-997	228-455	-
TPH	499	52,400-60,000	5400	-
Vactor Sediments				
Copper	24-28	36	88-229	-
Lead	69-92	91	109-175	-
Zinc	106-138	208	219-338	-
TPH	401-1293	-	2197	276
Vactor Water				
Copper	0.120-0.933	0.265	1.481-3.418	5.456
Lead	0.600-1.300	0.510	3.835-5.775	28.478
Zinc	0.608-2.498	3.057	5.672-10.200	26.754
TPH	5.2	-	8.2	7.7

[1]ppm = parts per million (mg/kg for solids; mg/L for liquids)

TABLE 9-6. Percentages of Washington State Catch Basin and Vactor Waste Samples Exceeding TCLP[1], MTCA[2], and Pretreatment[3] Standards, by Land Use (from Jacobson, 1993).

Type of Waste/ Contaminant (Legal Standard)	Residential % × No. of Samples	Commercial % × No. of Samples	Industrial % × No. of Samples	Highway % × No. of Samples
Solids				
Lead (TCLP)	43% × 35	60% × 35	71% × 21	-
TPH (MTCA)	78% × 14	100% × 5	80% × 5	-
Vactor Water[3]				
Copper (2.0 mg/L standard)	0% × 11	0% × 4	50% × 12	44% × 9
Copper (3.0 mg/L standard)	0% × 11	0% × 4	25% × 12	44% × 9
Copper (8.0 mg/L max. grab)	0% × 11	0% × 4	17% × 12	22% × 9
Lead (1.5 mg/L standard)	9% × 11	0% × 4	100% × 12	89% × 9
Lead (2.0 mg/L standard)	9% × 11	0% × 4	92% × 12	78% × 9
Lead (3.0 mg/L standard)	0% × 11	0% × 4	75% × 12	78% × 9
Lead (4.0 mg/L max. grab)	0% × 11	0% × 4	50% × 12	78% × 9
Zinc (1.5 mg/L standard)	36% × 11	25% × 4	100% × 12	100% × 9
Zinc (4.0 mg/L standard)	27% × 11	25% × 4	92% × 12	78% × 9
Zinc (5.0 mg/L standard)	9% × 11	25% × 4	92% × 12	67% × 9
Zinc (10.0 mg/L max. grab)	0% × 11	0% × 4	25% × 12	55% × 9

[1]Toxic Characteristic Leaching Procedure (US EPA) [2]Model Toxic Control Act (enacted in Washington state) [3]Pretreatment standards are from Lynnwood, Everett, and Seattle, WA.

water samples from industrial and highway areas frequently surpassed the highest waste-water treatment plant pretreatment standards for all three metals. Thus, vactor liquids from these land uses would certainly require pretreatment before discharge to wastewater treatment plants.

Sediments collected from Tacoma, Washington catch basins one year after they were cleaned were significantly less contaminated than samples collected from the same catch basins before cleaning. ***These results strongly suggested that annual cleaning of catch basins helps to reduce contaminant levels in wastes***. By controlling contamination levels in catch basin wastes through regular cleaning, stormwater utilities could reduce hazardous waste disposal costs. Similar results are likely to be attained in larger treatment facilities, which can accumulate sediments over a longer periods than catch basins.

As part of the reevaluation of Florida's policy on the land application of solid wastes, including sediments from stormwater systems, Livingston and Cox (1995) summarized data from Florida stormwater investigations. A comprehensive review of the stormwater literature found 17 reports which included data on the concentrations of contaminants within stormwater system sediments. These investigations contained considerable data on concentrations of heavy metals and nutrients in stormwater sediments but relatively little data on organic contaminants such as petroleum hydrocarbons. More data were available on stormwater sediments from wet detention systems than from infiltration or filtration practices.

Table 9-7 summarizes the concentrations of heavy metals in stormwater sediments from different types of BMPs, while Table 9-8 summarizes the concentrations of heavy metals in the sediments of BMPs serving different land uses. The data in both tables are for surficial sediments - the top one inch. Five of the sites also included data from different layers of the stormwater sediments. ***As with the data from Washington state, the concentrations of heavy metals were highest in surficial layers, but diminished rapidly within the top eight inches of sediments***.

Livingston and Cox (1995) presented the following conclusions on the concentrations of contaminants in stormwater system sediments in Florida:

- Stormwater sediments, especially in the top one inch of sediment, can exceed Florida's Clean Soil Criteria for chromium and lead. The average chromium concentration in the top inch of sediments from wet detention systems (83.3 ug/g) and from dry swales (69.7 ug/g) exceeded the 50 mg/kg clean soil criterion. However, of the 430 samples from wet ponds, less than 20 percent had chromium concentrations above the clean soil criterion. In sediments from dry swales, chromium concentrations exceeded 50 mg/kg more frequently. All nine top layer samples and two of the 0-4 inch samples had chromium concentrations above this value. The average chromium concentration in the top inch of swale sediments was 69.7 mg/kg while the average in the 0-4 inch samples was 51.3 mg/kg.

- The average lead concentration in the top inch of sediments from a retention system, wet ponds, dry swales, wet swales, and roadside shoulders exceeded the 108 mg/kg clean soil criterion as did sediments collected by street sweepers. Sediment lead concentrations greater than this level were found in the sediments from seven wet ponds, all three dry swales, the lone wet swale, all four highway shoulder sites, and in one street sweeper investigation, one conducted in 1977 when leaded gas was still available. Even the deeper sediment layers exceeded the clean soil criteria for lead in the FDOT highway ponds (0-4 inch layers), and at both the East-West Expressway dry swales and the Interstate 4 wet swale (0-4 and 0-8 inch layers).

- Table 9-8 compares the levels of heavy metals in sediments from stormwater systems serving different land uses. Similar to

TABLE 9-7. Comparison of Heavy Metal Concentrations (ug/g) in the Top One Inch of Sediments from Various Types of Stormwater Systems in Florida.

BMP	No. Obs/ Sites	Cd	Cr	Cu	Ni	Pb	Zn
Dry Retention Basin	3/1	1.00	4.00	13.00	NA	200.00	100.00
Wet Detention Basin	430/21	3.60	83.30	25.60	13.10	227.00	150.30
Grassed Swale - dry	9/3	5.50	69.70	89.50	35.60	1060.0	497.30
Grassed Swale - wet	5/1	1.60	8.40	14.60	6.00	438.60	112.60
Exfiltration Trench	2/1	3.00	14.50	8.00	NA	80.00	80.00

TABLE 9-8. Comparison of Heavy Metal Concentrations (ug/g) in the Top One Inch of Sediments from Florida Stormwater Systems Serving Various Land Uses.

Land Use	No. Obs./ Sites	Cd	Cr	Cu	Ni	Pb	Zn
SF Residential	75/3	2.10	17.40	9.10	8.00	29.20	29.90
MF Residential	15/1	1.20	3.20	21.20	7.20	32.00	22.20
Commercial	17/4	2.30	14.20	26.30	6.40	110.20	150.90
Mixed Com/Res.	57/3	2.70	14.80	26.10	4.00	351.60	176.10
Highways	313/14	5.70	51.30	54.00	26.10	676.80	298.40

stormwater loadings, concentrations of trace metals in sediments increased with the intensity of the land use and the associated stormwater loadings. As expected, because of the characteristics of pollutants left on surfaces over which motor vehicles travel, sediments in BMPs capturing highway runoff have the highest concentrations of trace metals. The average chromium concentration in highway BMP sediments barely exceeds the clean soil criterion (51.3 mg/kg vs 50 mg/kg). However, the average lead concentration in sediments from BMPs serving highways (676.8), industrial (578), mixed commercial/residential (352),
and commercial (110.2) land uses exceeds the clean soil criterion for lead (108 mg/kg).

- Table 9-9 contains data allowing a comparison of heavy metal concentrations in three different layers of stormwater BMP sediments. As expected, concentrations decline as the loose surface sediment is combined with more consolidated deeper sediments. However, even in the samples compositing the top 0-8 inches of BMP sediments, lead concentrations in sediments from highway wet ponds and dry swales can exceed the clean soil criterion.

- A growing concern among ecologists is the effects of petroleum hydrocarbons and volatile organic compounds on the biota of water bodies receiving stormwater discharges. Unfortunately, few investigations have been undertaken to determine the ecological effects of these materials, which have become almost ubiquitous in the urban environment

Table 9-9. Concentrations of Heavy Metals (ug/g) in the top 1 inch, top 0-4 inches, and top 0-8 inches of Sediments from 6 Florida Stormwater Systems.

	Land Use/Site Name/Reference					
Metal (Sites/Obs.)	SF Res. Essex Point Harper 1988 (1/6)	MF Res. Unknown Harper 1988 (1/15)	SF Res. Greenview Yousef 1990 (1/48)	Comm. Hwy. Int. Mkt. Pl. Harper 1988 (1/4)	Hwy FDOT Ponds Yousef 1990 (9/161)	Swales Harper 88 USGS 88 (3/9)
Cd	1.6	1.2	2.3	2.9	15.0	5.5
	1.5	0.9	2.7	1.8	7.4	3.5
	1.5	0.3	ND	1.1	ND	ND
Cr	7.2	21.2	9.5	12.2	61.0	69.7
	5.8	9.8	8.7	11.3	28.5	51.3
	5.2	6.2	ND	8.9	ND	ND
Cu	9.0	3.2	11.8	6.8	28.0	89.5
	7.5	1.8	7.0	4.7	10.6	77.4
	7.3	1.4	ND	3.4	ND	ND
Ni	3.0	7.2	8.0	6.4	52.0	35.6
	2.5	3.8	4.7	5.1	33.9	20.9
	2.0	2.7	ND	6.3	ND	ND
Pb	13.8	32.0	34.2	46.0	374.0	1060
	11.2	14.0	17.7	31.5	141.9	653.5
	9.9	9.3	ND	22.8	ND	ND
Zn	11.6	22.2	31‘.0	127.0	161.0	497.3
	6.9	13.3	12.4	68.5	48.4	269.0
	5.7	10.4	ND	36.8	ND	ND

ND = Not determined for the soil profile listed due to insufficient data.

because of civilization's reliance upon the motor vehicle. Additionally, very few investigations have determined the levels of volatile organic aromatics or petroleum hydrocarbons in stormwater BMP sediments. Only six Florida studies included measurements of these contaminants, with only the Lake Tuscawilla project in Ocala providing data that allows a comparison of stormwater sediment characteristics to the clean soil criteria. The levels of total recoverable petroleum hydrocarbons and the polynuclear aromatic hydrocarbons in sediments from Lake Tuscawilla greatly exceeded the clean soil criteria. The cause of these elevated levels is believed to be a leaking underground fuel tank. This required the City of Ocala to "treat" these sediments by spreading them in sludge drying beds, exposing them to light and oxygen.

- Another interesting observation can be made with respect to lead concentrations in the soil along the edges of highways. At the edge of the pavement and in a swale located 18 feet away from the pavement's edge, the lead concentrations greatly exceeded the clean soil criteria in the top two inches of soil. Does this mean that all soils adjacent to highways need to be cleaned up or disposed? Of course, this investigation was conducted back in 1978 before leaded gas had been eliminated, and the results should be different today.

- A key question that must be addressed is whether sediments taken from stormwater BMPs are a "hazardous waste" because of their toxicity? ***Based on Florida data, stormwater sediments generally are not toxic based on the results of TCLP tests. Not a single sample in the data base exceeded the TCLP limits that would cause stormwater sediments to be classified as a hazardous waste***.

To augment the information summarized above, the Florida Dept. of Environmental Protection Stormwater Section conducted additional sampling of stormwater sediments in late 1996. A primary goal of this effort was to obtain data on organic contaminants such as petroleum hydrocarbons and pesticides. Samples were collected from twelve different stormwater BMPs serving eight different land uses. A total of 102 samples were collected by 14 different local stormwater programs throughout the state of Florida.

Each sample was analyzed for physical characteristics and 128 pollutants including:
- Total solids
- Sediment grain size
- Total Organic Carbon
- Metals - As, Cd, Cr, Cu, Ni, Pb, Zn
- 26 Chlorinated pesticides and PCBs
- 34 Volatile Organics
- 60 Semivolatile PAHs, phthlates, phenols
- Total recoverable petroleum hydrocarbons

In addition, Toxicity Characteristic Leaching Procedure (TCLP) was conducted on sediments collected at 44 sites.

The results of this project confirm the results and recommendations of Livingston and Cox (1995). Notable results include (Cox et. al. 1997):

- Only about 10% of the 15,506 analyses performed resulted in levels above the laboratory minimum detection levels (MDL).
- Only 53 pollutants were found in detectable concentrations. Similar to previous studies, several traffic related metals (chromium, lead, and zinc) were found at all sites, while copper, cadmium, nickel, and arsenic were detected in samples at frequencies of 94%, 72%, 67%, and 64% respectively.
- Of the 35 organic compounds detected, only 8 were found in at least half of the 87 sites. These include total recoverable petroleum hydrocarbons (TRPH), chlordane, pyrene,benzo(b)fluoranthene, fluoranthene, chrysene, DDE-p,p', and benzo(a)pyrene.
- TRPH were found at 78 sites while the pesticide Chlordane was found at 71 sites (82%). Chlordane previously was widely used for termite control but was banned in 1989. While detectable levels of Chlordane would be expected in sediments from older stormwater BMPs, high concentrations also were found in sediments recently collected by street sweepers and catch basins.
- The NURP results found that only about 20% of stormwater samples had detectable levels of organic pollutants and that only four PAHs were found in more than 10% of the samples (EPA, 1983). However, these same four PAHs were found in 47 to 64% of the stormwater sediment samples. A total of 13 PAHs, 2 pesticides, 2 phthalates, and PCB

1260 were found in 10 percent of more of the sediment samples.

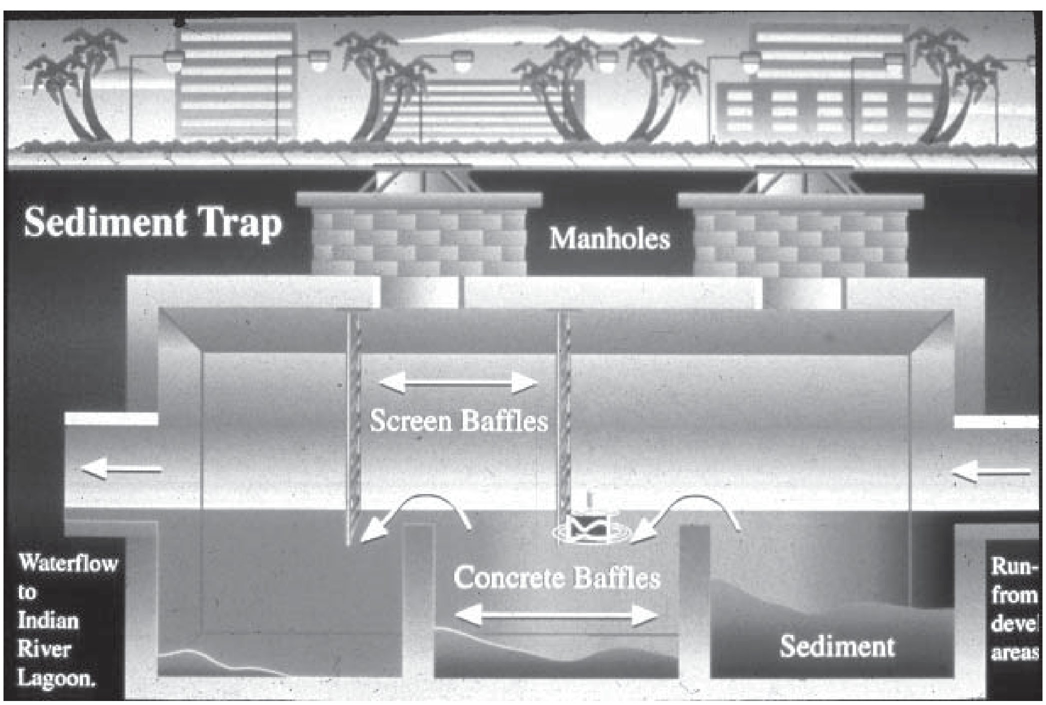
- Only 3 of the 36 organic pollutants tested for TCLP were detected at levels above the minimum detection limit. These included toluene, total xylenes, and m,p-cresols. None of the levels exceed RCRA levels.

- All four metals (As, Cd, Cr, Pb) tested for TCLP were detected in levels above the MDL. Only two lead samples from canals in South Florida exceeded TCLP levels for hazardous wastes.

3.1. Contaminants Levels in Sediments of Ultra-Urban BMPs

Confined sand filters and baffle boxes are two BMPs which often are used on highly impervious, land-limited sites. Because of their inherent design and limited storage volume, these two BMPs typically require frequent maintenance to remove accumulated sediments or clogged filter sand.

In a Seattle, Washington study to monitor the performance of a sand filter system, filter sand and sediment were analyzed for TCLP metals, copper, zinc, FOG, and TPH. ***After seven months of filter operation at a busy shipping facility, no sample came close to violating hazardous and dangerous waste standards for metals. However, TPH concentrations in settling chamber sediments greatly exceeded the Washington Model Toxics Control Act hazardous waste criterion of 200 mg/kg***. Results for the two monitored filters were close, 25,454 and 34,018 mg/kg, despite their divergent water quality conditions. None of the full sand cores closely approached the Model Toxics Control Act limit for TPH. However, the two most concentrated segments, taken from the 0 to 1.2 inch segment of the sand cores, did exceed the criterion.



Baffle box used to retrofit stormwater systems along the Indian River Lagoon, Florida.

As part of the Indian River Lagoon (Florida) National Estuary Program's efforts to reduce stormwater pollutant discharges to the lagoon, local governments have installed several three chambered baffle boxes. These are underground, "on-line" systems installed at the end of existing storm sewers before they discharge to the Indian River Lagoon. The treatment effectiveness of these baffle boxes was investigated by Royal and Vanderbleek (1994). They collected samples from each of the three chambers of a baffle box and analyzed them for heavy metals. The concentrations of all heavy metals were extremely low. This probably reflects the frequent pumping out of the baffle boxes. The boxes, which accumulated over 8,500 pounds of sediment in less than six month of operation, are cleaned out approximately every four months. The interval between pump outs has varied from one to six months.

4. RECOMMENDATIONS ON SEDIMENT TESTING

4.1. Storm Facility Solids and Liquid Waste Testing

Maintenance personnel should examine the appearance and odor of solids and liquids removed from stormwater BMPs to determine whether chemical analyses are necessary. Personnel should be alert to an especially oily appearance, coloration by antifreeze, or odors of gasoline, solvents, hydrogen sulfide, or other noxious substances. Hazardous waste will stain, corrode, or otherwise alter the look of catch basins. These characteristics could be signs of illicit dumping.

Material from a contaminated catch basin should not be pumped into a vactor truck containing cleaner wastes. Mixing wastes of differing qualities could contaminate the whole load and make its disposal more difficult. The suspected hazardous waste should be analyzed to determine the appropriate disposal method. Field test kits are available to detect petroleum and polyaromatic hydrocarbons.

Maintenance workers should also note the land uses in the catchment of a stormwater facility. Stormwater sediments from industrial areas and highways are much more likely to exceed hazardous waste standards than those from residential and commercial areas. Personnel should be particularly vigilant when any of the following activities are present in a catchment: electroplaters; industrial parks; vehicle repair facilities; wrecking yards; cemeteries; golf courses; pesticide blending and mixing areas; electrical vaults; hydraulic lift pumps; animal product handlers; and waste storage areas.

Characterization of stormwater facility wastes is a central feature of the Washington State Department of Transportation's (WSDOT) strategy to minimize waste disposal costs by using clean wastes in maintenance activities. WSDOT follows a two-step disposal process, consisting of interim and final disposal. In the interim stage, waste will be characterized to determine proper final disposal. Vactor waste will be placed a minimum of 100 feet from property boundaries, surface water bodies, and water supply wells. Following the decanting of vactor liquids, the solids are to be placed on impermeable surfaces surrounded by berms of straw bales or dirt. The piles will be covered by plastic or other impervious materials to minimize the amount of water that drains through the solids. Waste piles are not to exceed 100 cubic feet in volume. The dirtiest wastes will be segregated from those that are relatively cleaner. Wastes will be characterized by appearance, odor, and field test kits that detect total petroleum and polyaromatic hydrocarbons.

WSDOT will perform periodic laboratory analyses to confirm the results of the test kits. The ***selection of stormwater sediment pollutants for laboratory analysis depends on the***

location of the facility and the initial characterization of the waste. Sediments from stormwater systems in heavily urbanized and industrial catchments should be analyzed for petroleum hydrocarbons (TPH), FOG, toxic metals (*e.g.*, lead, zinc, copper, and cadmium), nutrients (*e.g.*, phosphorus), and, if appropriate, organic pesticides, which can accumulate on pond bottoms. ***The Washington Department of Ecology recommends that street waste solids be tested for chromium, TPH, and PAHs, the pollutants that are the most likely to exceed the criteria for street waste solids designation (i.e., acceptable for reuse)***. Vactor wastes collected by the WSDOT will be periodically analyzed for total metals, TCLP metals, TPH, gasoline, diesel, heavy fuel hydrocarbons, PAH, and benzene-toluene-ethyl benzene-xylene (BTEX).

4.2. Testing of the Sand Filter Medium and Accumulated Sediments

Key analytes to determine sediment and sand disposal requirements are fats, oils, and grease (FOG), TPH, and the TCLP and other metals. If TCLP metals concentrations in solids are reported in mg/kg, they can be compared to TCLP standards (defined in mg/L) by multiplying the TCLP standard by 20 to convert to mg/kg. This approximate equivalents method is used by the US EPA. The equivalents method implicitly assumes that the analytic method for determining metals concentrations in solids was followed precisely and that the metals were completely extracted. The presence of oil and grease in sediments can reduce extraction efficiency. Because the dilution factor of 20 is extremely conservative, samples found to exceed hazardous waste standards according to the equivalents method frequently do not exceed TCLP standards in reality.

5. RECOMMENDATIONS ON THE DISPOSAL OF STORMWATER SEDIMENTS

5.1. Waste Collection Considerations

A drawback to vactor trucks is that they can mix wastes that are relatively clean with those that are very dirty. An effective, but costly solution would be to have “clean” and “dirty” trucks. Alternatively, cleaning only facilities associated with a single type of land on a given vactor truck run would reduce the risk of mixing wastes with different contaminant levels. ***Because of their great potential to cause contamination, vactor wastes should never be mixed with street sweepings or debris from ditch cleaning***.

5.2. Disposal Methods

Guidelines are necessary, but generally do not exist, for disposing sediments from stormwater BMPs. The best programs now send them to lined municipal landfills unless they fail a “looks bad and smells bad” test. If wastes fail to pass this subjective test, they are treated as hazardous wastes and tested.

Reuse, recycling, and other non-landfill end solutions for stormwater sediments can help to reduce disposal costs. Many state solid waste laws, such as Washington's Solid Waste Management Act and its Model Toxics Control Act, give the highest priority to this waste handling strategy. When disposal of stormwater system wastes is necessary, they should be transported to lined landfills where they can be used for cover material or, if necessary, to hazardous waste disposal facilities.

In Washington state, some entrepreneurs have set up an incineration facility at an old, unused cement plant kiln to cook vactor wastes. This has been shown to be a cost-effective option when compared to landfilling the wastes.

Where only petroleum hydrocarbon contamination prevents the recycling of storm facility wastes, they could be bioremediated at an approved pit site. The WSDOT (1994) classifies treated soils as follows:

Class 1 Soils — These soils contain residual concentrations of petroleum contaminants at or below analytical detection limits. They are considered clean and can be used as fill for any project.

Class 2 Soils — These soils contain detectable levels of petroleum contaminants below the Cleanup Regulation Method A cleanup standard — 100 parts per million of TPH. Appropriate uses include fill or other uses that will not cause a threat to human or environmental health.

Class 3 Soils — These are soils with high levels of heavy hydrocarbons that may not meet cleanup standards even after treatment. Soils receiving adequate treatment should be able to meet the cleanup levels for light petroleum fractions. Those soils that cannot attain cleanup standards should be used at the original site or disposed of in an existing, permitted municipal landfill.

Class 1 soils can be used in the following applications: road and parking lot subgrade; road construction fill; street sweeping sand; pipe bedding, except for drinking water pipes; utility trench backfill, except for drinking water pipes; controlled density fill; fill in commercial and industrial zones; prefabricated concrete manufacturing; Portland cement manufacturing; asphalt manufacturing; daily cover or fill in permitted landfills, provided they are dewatered; or other end uses approved by local health departments. Street waste solids should not be reused for surface mining reclamation, in a wastewater disposal mound system, or as cover or fill in an inert demolition waste landfill.

5.3. Decant Water Disposal

Disposal of decant water picked up by vactor trucks is another important problem. Not only do storm drain liquids contain pollutants in their own right, but the vactoring process could further contaminate the water column by resuspending solids. Vactor trucks must decant water two or three times per day to make room for more solids. A common and practical method of decant water disposal is to drain it into catch basins in nonsensitive areas. Another practice is to discharge decant water into sanitary sewers. However, discharge of vactor waste into sanitary sewers may still allow pollutants to enter surface waters if treatment at the wastewater treatment plant is inadequate. Moreover, high toxics loadings can also upset biological processes at wastewater treatment plants.

The three options that have been suggested for managing decant water are (1) reducing the amount of liquids removed from storm facilities; (2) eliminating discharges in the field; and (3) using field settling sumps. There is a lack of data on the filtration of vactor liquids in the field, so this method is not recommended. Similarly, data on the treatment efficiencies or the maintenance safety of stormwater inserts and online filtration systems are not widely available.

Reducing the amount of liquids removed from stormwater facilities (option 1) would be accomplished by modifying vactor suction tubes to reduce the amount of liquid removed during cleaning. To eliminate field discharges (option 2), liquids are transported in vactor trucks with the solids and treated at decant stations. Decant station treatment techniques include (1) using drying pads and lagoons to eliminate all discharges; (2) gravity settling of solids and possible treatment with a coalescing plate oil/water separator, followed by discharge to a sanitary sewer; and (3) treatment with a sand or a sand/peat filter. One decant station design includes a 9-foot deep sump for the settling of solids from decant water. Solids are removed approximately every other day. Some cities dewater combined liquid and solid street wastes and filter the liquids before discharging to sanitary sewers.

The field sump method (option 3) would use gravity settling over 4 to 8 hours to reduce decant water contamination. The sump could be any type of detention or retention BMP. Sumps, vaults, and tanks are the most practical facilities for settling because they can be installed in a wide variety of locations, are easily maintained, and solids can be removed by vactor truck. A modified catch basin could also serve as a sump. Use of twin sumps would allow one to settle solids and drain while the other received new wastes.

The removal of solids from vactor liquids by settling has been found to occur at the following rates: 54% removed after 0.5 hour; 67% after 1 hour; 79% after 2 hours; 87% after 3 hours; 90% after 4 hours; and 97% after 8 hours. In five hours, the settling of 1750 pounds (795 kg) of solids from 1500 gallons (5678 liters) of water reduced pollutants by the following amounts: sediments -- 55 to 85%; chemical oxygen demand -- 11 to 54%; total organic carbon -- 6 to 35%; total phosphorus -- 4 to 50%; total nitrogen -- 2 to 61%; zinc -- 4 to 60%; and lead -- 31 to 83%.

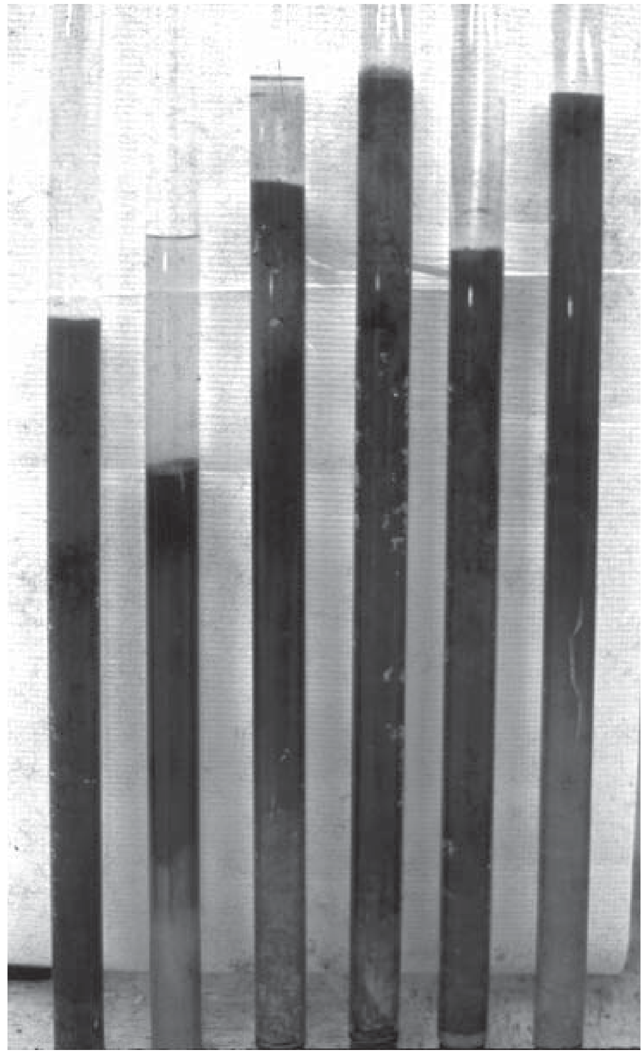
5.4. Sand Filter Waste Disposal Methods

The researchers in the Seattle sand filter monitoring study decided that settling chamber water could be drained through the sand bed instead of removed for off-site disposal when cleaning of the chamber became necessary. The rationale for this decision was that, because sand filters are flow-through systems, settling chamber water normally is treated by the sand bed anyway. Thus, disposal regulations do not directly affect the settling chamber water, provided that it is treated by the sand bed. However, when siphoning liquid out of the settling chamber, maintenance personnel should be careful not to resuspend sediments. Alterna-

Settled vactor solids at Bellevue, WA. vactor decant station.
Photo courtesy of Ventilation Power Equipment, Inc. , Seattle.

tively, if costs are not an objection and appropriate methods are available for disposal of the liquid and sediment, removing both materials simultaneously could reduce time and labor costs.

The variable sand core sampling results from the Seattle study created a dilemma about how to dispose of filter sand, when removal became necessary. Because inconsistencies in concentrations could make identifying the portions that are hazardous waste difficult, occasional disposal of the entire upper layer might be the best option. Maintenance should be fairly infrequent, only every few years, and generate a relatively small volume of waste (top few centimeters of the soil column). Bioremediation, the decomposition of organic molecules by microorganisms, has been well demonstrated for hazardous material and contaminated soil renovation. However, this technique needs to be assessed for use in stormwater sand filters. Full rejuvenation by bioremediation might not be possible when mineral solids cause the filter to clog.



Sediments from stormwater discharges accumulated on the bottom of Megginnis Arm, Lake Jackson, in Florida before implementation of the state's stormwater treatment rules in 1982. Removal of sediments from water bodies and the restoration of water bodies is much more difficult and expensive than the implementation of BMPs and their proper maintenance.

Chapter 10
Information Sources

Information used in this publication was obtained from a variety of sources which are listed in this chapter. The interested reader is urged to review these information sources if more detailed information is desired. Additionally, because of the rapid growth of the stormwater management state-of-the-art, readers are encouraged to consult more recent literature to assure that they have the most recent data and information.

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