Tennessee

Guide to the Selection & Design of Stormwater Best Management Practices (BMPs)

A Guide for Phase II MS4 Communities for Protecting Post-construction Stormwater Quality and Managing Stormwater Flow

prepared by

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FORWARD - BACKGROUND & BASIS FOR MANUAL

Water Quality Issues

Since the passage of the Clean Water Act (CWA), the quality of our Nation's waters has improved dramatically. Despite this progress, however, degraded water bodies still exist. According to the 1996 National Water Quality Inventory, a biennial summary of State surveys of water quality, approximately 40 percent of surveyed U. S. water bodies are still impaired by pollution and do not meet water quality standards. A leading source of this impairment is polluted stormwater runoff. In fact, according to the Inventory, 50 percent of impaired rivers in the U. S. are affected by urban/suburban and construction sources of storm runoff.

Tennessee has approximately 60,200 stream miles and 537,000 publicly-owned lake acres within its boundaries. All of the streams and lakes in Tennessee are classified, at minimum, for fish and aquatic life and recreation (TDEC, 2000), in concert with Congress' national goal that all waters be both "fishable and swimmable." The 2000 305(b) water quality assessment report for Tennessee indicates that, for the 40 percent of the streams that have been assessed to date, almost a third of Tennessee's streams still do not fully support designated uses for aquatic life and recreation (TDEC, 2000). Of the approximately 99% of the lake and reservoir areas that have been assessed, about 7 percent have impaired water quality for supporting aquatic life and about 20 percent have recreational impairment. While no single cause of stream and river impairment is dominant, conventional pollutants such as siltation, suspended solids, nutrient enrichment and organic enrichment/low dissolved oxygen affect the most river miles. Major sources of these pollutants are agricultural activities, hydro-modification, as well as municipal point sources. Other sources of impairment include urban runoff/storm sewers, construction activities, and industrial point sources.

This manual provides general guidance in developing and implementing *post-construction* best management practices (BMPs) for both stormwater runoff quality and quantity (flow) in the designated small Phase II stormwater communities in Tennessee. Currently, there are 47 cities and counties in Tennessee that are subject to the Phase II program, because they are specifically listed in the EPA rule and because part or all part of the local government Municipal Separate Storm Sewer Systems (MS4s) are in urbanized areas having minimum residential populations of 50,000 people and a minimum average density of 1,000 people/square mile.

In addition, the EPA Phase II rule mandates that the State of Tennessee NPDES permitting authority (PA), the Department of Environment and Conservation (TDEC), examine small MS4s outside of urbanized areas having 10,000 or more population and densities of at least 1000/square mile, to evaluate whether stormwater discharges result in, or have the potential to result in, exceedances of water quality standards. Approximately 23 Tennessee communities fall into this category.

Other cities with populations over 10,000, regardless of population density, are also being examined by the State. At least 4 cities fall into this category. Additional areas where population growth rates are high are also being examined because of their future potential for negative impacts on nearby streams if appropriate stormwater management programs are not implemented. Five counties currently fall into this classification.

The reader is referred to TDEC's Phase II stormwater communities in Tennessee for the current listing of which local government MS4s in each of the above urban categories will be regulated. Appendix D lists the most recent Phase II Stormwater Communities in Tennessee, based on the 1990 census data.

While this manual focuses on water quality and quantity issues associated with post-construction development, construction and development activities have been shown to contribute large quantities of sediment and silt to water bodies during precipitation events. A companion manual, Tennessee Erosion & Sediment Control Handbook, has been recently published by TDEC for protecting state waters through the use of BMPs during land disturbing or construction activities (TDEC, 2002).

Water Quantity Issues

Local government officials and private owners have a responsibility to consider both the rules of law for liability for stormwater runoff quantity issues and applicable state and federal requirements related to stormwater quantity at the local level. These requirements and responsibilities are summarized as follows.

Water use rights

Existing water use and drainage law in Tennessee result mainly from judicial decisions stating the application of the common law in this state. There has been little statutory treatment of individual rights and obligations. The doctrine of riparian rights, which prevails in most of the eastern United States, is the basis for the existing law of Tennessee for controlling rights to the *use* of water in well-defined streams. As applied in Tennessee it has been referred to as the "reasonable use" doctrine and can be stated as follows (Marquis, et al., 1955):

> ...each riparian owner has an equal right to have the stream flow through his land in its natural channel, without material diminution in quantity or alteration in quality but with this limitation or qualification, however, that each proprietor is entitled to the reasonable use of the water for domestic, agricultural or manufacturing purposes (American Association, Inc. v. Eastern Kentucky Land Co., 2 Tenn. Ch. App. 132, 173 (1901), affirmed by Tenn. Sup. Ct. without modification).

Rights to natural stream flow in Tennessee are reinforced in another early case:

> The owner of land, across or over which a stream of water flows, has a right to have it flow over his land in its natural channel, without unreasonable detention, undiminished in quantity, and unimpaired in quality, except so far as it inseparable from a reasonable use of the water of the stream for the ordinary and useful purposes of life by those above him on the stream. (Tenn. 1901, Cox v. Howell, 65 S.W. 868, 108 Tenn. 130, 58 L.R.A. 487)

Drainage law

Many of the controversies over water issues in Tennessee have arisen when excessive water flowing from one owner's property is allowed to physically *invade and damage* another's property, rather than over a riparian owner's *right* to use the water. Cases include the flooding of upper land by the backwater from construction of dams or other obstructions; liability is generally imposed in such cases, except for injuries caused solely by floods which are so great as to be unforeseeable and to constitute acts of God (Hurley v. American Enka Corp., 1950). A large group of cases involve pollution, where the courts have consistently followed a strict rule of liability if the pollution results in material injury (H. B. Bowling Coal Co. v. Ruffner, 1906).

The consequences from *excessive* stormwater runoff can be immediate and devastating, resulting in flooding and damages to lower or adjacent lands. Common law generally divides stormwater runoff into two categories: surface water and natural watercourses. Surface water is defined as water that falls to the ground from the sky, diffuses as overland flow on the surface of the land, and follows no defined course or channel. Surface water can also include that which arises from springs. Some or all surface water may be lost by being dispersed over the ground through infiltration and evaporation. After surface water has become part of a stream in a watercourse, the runoff is no longer defined as surface water and the courts generally no longer recognize it as surface water.

A natural watercourse is a channel with a defined bed and banks through which water normally passes as a body or stream during the seasons and at times when streams in the region usually flow. Alterations to a natural watercourse, such as the construction of conduits or other improvements in the bed of the stream, do not generally affect its status as a natural watercourse.

Typically, three basic common law rules govern liability for stormwater drainage and runoff: (1) the civil law rule, which prohibits interference with the natural flow of surface water; (2) the common enemy rule, under which each property owner can fight the water problem the best way he can; and (3) the reasonable use rule, which permits a lower property owner to make "reasonable" alterations to protect against excessive stormwater runoff, in hardship situations where strict application of the civil law rule might prevent the lower landowner from improving his land or using it as he would

otherwise have a right to use it.

With respect to damage from hostile surface waters, Tennessee, along with several other states, generally adheres to the civil law rule that accords the owner of higher land an easement for the drainage of surface water across lower land to which it naturally flows and forbids any injurious interference or obstruction with such flow by the lower owner (Thomas, et al, 1998; Louisville & N. RR. V. Hays, 1883). As part of this rule, it is held that the upper owner cannot artificially increase the natural quantity of water or change its natural manner of flow by collecting it and discharging it upon the lower land at a different place or in a different manner from its natural discharge (Louisville & N. R. R. v. Hays; Slatters v. Mitchell, 1938).

The civil law rule in Tennessee has been upheld in several cases involving issues such as drainage easements; obstructions; artificial and general drainage; natural drainage and watercourses; diversion, overflow, breakage or seepage; pollution; and artificial ponds, reservoirs, and channels and dams. Court decisions relating to drainage cases, which reinforce the civil law rule application to natural water courses and surface waters in Tennessee, are cited and summarized in the appendix of this manual.

Municipal permits

The issue of a municipality's liability arising out of creating a nuisance is documented in cases relating to sewer construction (City of Columbia v. Leintz, 39 Tenn. App. 350, 282 S. W. 2d 787 (1955) and Kolb v. mayor of Knoxville, 111 Tenn. 311, 76 S. W. 823 (1903). However, judicial decisions do not generally hold municipalities responsible in their power to grant or deny building permits and resulting actions of private enterprises (Miller v. City of Brentwood, 548 S. W. 2d 878 (Tenn. App. 1977) and Zollinger v. Carter, 837 S. W. 2d 613 (Tenn. App. 1992).

For example, in Miller v. City of Brentwood, it was held that,

[I]n spite of the recent propensity of some courts to undertake to supervise and direct the activities of other branches of government, none has yet been so bold as to hold a local government liable for failure to assure that a building project would not injure its neighbors before issuing a permit for construction.

The court further states that,

. . . no right of action is recognized against a municipality for issuing a permit for construction in accordance with existing laws and regulations. Correspondingly, there is no authority for the Courts to enjoin the issuance of a permit, otherwise lawful, for the reason that its use might result in a private injury.

In Zollinger v. Carter, the court ruled that,

[W]e are of the opinion and hold that approval of the design and acceptance of a drainage

system by a municipality does not absolve a defendant (developer) from liability where it is demonstrated by a preponderance of the evidence that the injury (to adjoining landowner) would not have occurred but for the activities of the defendant.

Local regulation

Tennessee's enabling legislation (T. C. A. 13-701 Amended) empowers local communities to regulate building construction and to allow establishment of special districts and zones for purpose of promoting the health, safety, morals, convenience, order, prosperity and general welfare of the public. Such regulations include, but may not be limited to

- Building codes
- Detention pond ordinances
- Subdivision regulations
- Drainage & stormwater management ordinances
- Stormwater utility districts

When effectively written and enforced, these tools represent potent instruments for managing both stormwater quality and quantity. The appendix contains examples of both model stormwater and utility ordinances (Appendices B and C).

Enforcement of regulations is especially important to effective stormwater management. A recent University of Tennessee study of the performance of 20 stormwater detention ponds in five different regulatory jurisdictions in the Knoxville area showed many technical deficiencies and inconsistencies in both their design and construction (Tschantz and Romans, 1997; Romans, 1997). Most of the problems stemmed from poor or defective construction. For example, 17 of the 20 ponds had storage volumes less than that indicated on the plans and specifications. Some of the differences between design and field conditions were deemed large enough to have a very negative impact on intended performance, and hence, downstream flooding. Several recommendations were made to developers and owners, engineers, the public, and public works officials. Among these recommendations, the study urged local officials to make on-site inspections during construction of detention ponds and to require "As-built" surveys as a quality control measure to confirm that the designer's plans are constructed according to intent to ensure effective performance.

Tennessee laws

The seriousness of water pollution and other water-related problems have produced statutory control administered by state and federal agencies. The following Tennessee laws and standards affect local control and management of stormwater quality and quantity:

A. Safe Dams Act of 1973, TCA, Section 69-12-101, as amended 1991.

This act regulates the design and construction of dams. All dams greater than 20 feet in height or having volumes larger than 30 acre-feet must be approved by the state dam safety office. This act relates to stormwater management in that it limits the size of detention and retention ponds that may be constructed without approval.

B. The Water Quality Control Act, Title 70, Chapter 3, June 27, 1977, as amended 1994.

The purpose of this act is to "abate existing pollution of the waters of Tennessee, to reclaim polluted waters, to prevent the future pollution of the waters, and to plan for the future use of the waters". It also "enables the state to qualify for full participation in the national pollutant discharge elimination system (NPDES) established under Section 402 of the Federal Water Pollution Control Act". To accomplish these goals, the act implements a requirement for a permit before undertaking activities which may affect the waters of the state. These activities include "the alteration of the physical, chemical, radiological, biological, or bacteriological properties of any waters of the state", "the development of a natural resource... the operation of which will or is likely to cause an increase in the discharge of wastes into the waters of the state..", "the construction or use of any new outlet for the discharge of any wastes into the waters of the state", and others. The Water Quality Control Act is important to stormwater management issues because stormwater runoff is a source of pollution which can be regulated under this act.

C. State of Tennessee Water Quality Standards, Rules of the Department of Environment and Conservation, Bureau of Environment, Division of Water Pollution Control, Chapt. 1200-4-1, General Rules; Chapt. 1200-4-3 (General Water Quality Criteria), Chapter 1200-4-4 (Use Classification for Surface Waters), July 1995.

The Tennessee Water Quality Standards were established to fulfill a requirement of the Water Quality Control Act. Tennessee streams are classified according to use into categories such as domestic water supply, recreation, irrigation, and fish/aquatic life. Water quality criteria are established for each use classification and include factors such as dissolved oxygen, temperature, solids, mineral compounds, and toxic substances.

D. Memorandum of Agreement between The Tennessee Dept. of Agriculture and The Tenn. Dept. of Environment and Conservation, Division of Water Pollution Control, July 1995.

The purpose of this agreement is to establish "a cooperative... program of effective water quality protection associated with silvicultural and agricultural production activities". The document includes procedures for investigating water quality-related complaints in forestry operations.

E. Tennessee Department of Environment and Conservation, Division of Water Pollution Control, General Permits, Aquatic Resource Alteration Permit Program

(ARAPP), August 1996.

This program requires that a permit be obtained before undertaking any activity which may impact state aquatic resources. Activities requiring a permit include road crossings of waters, stream bank stabilization, sand and gravel dredging, utility line crossings, minor wetland alterations, alteration of wet weather conveyances, and others.

F. Creation of drainage and levee districts and assessments (Drainage law acts of 1909, etc.)

Federal laws and programs

Applicable federal statutes and programs which may be applicable to municipal stormwater quantity and quality management include the following:

A. Clean Water Act of 1972 (construction, NPDES permit, stormwater runoff)

Section 402 (dredging, filling, wetlands)

Section 404 (construction, NPDES permit, stormwater runoff)

The Clean Water Act addresses the problem of point source pollution by requiring a National Pollutant Discharge Elimination System (NPDES) permit for the discharge of any pollutants to navigable waters. The primary sources of point source pollution targeted by the act were discharges of industrial process wastewater and municipal sewage.

B. Water Quality Act of 1987

The Water Quality Act amends the Clean Water Act of 1972 to address the problem of nonpoint source pollution. It requires a permit for stormwater discharges associated with industrial activities and for discharges from storm drain systems in municipalities with populations greater than 100,000.

C. TVA Section 26a

Section 26a of the Tennessee Valley Authority Act of 1933, as amended, prohibits "….the construction, commencement of construction, operation, or maintenance…" in the Tennessee River or any of its tributaries of any structures "…. affecting navigation, flood control, or public lands or reservations…until plans for such construction, operation, and maintenance shall have been submitted to and approved by the (TVA) Board."

Plans for any (detention or retention) dams in the Tennessee River drainage basin of such size that their individual or cumulative failure would affect navigation, flood control, or public lands or reservations or interfere with interstate commerce are subject to review by the Tennessee Valley Authority under Section 26a.

D. National Flood Insurance Act of 1968

The National Flood Insurance Act requires communities to adopt measures to

control development in floodplain areas in order to be eligible for federal flood insurance. Zoning, building codes, subdivision regulations, and other ordinances adopted in order to comply with this act can be written to also address drainage issues.

Summary

The proper selection and implementation of BMPs can be a very effective means for protecting Tennessee's streams and lakes by reducing stormwater-generated pollution and avoiding costly flooding problems from post-construction development sites.

It is important, especially in a time of increasing insurance premiums and claims and lawsuits, that local governments need to be aware of its legal regulatory responsibilities in urban stormwater management for both water quality and quantity issues to protect themselves, as much as possible, against tort liability and to reduce the costs of such to the taxpayers, who ultimately must bear the cost for careless or negligent management of urban runoff.

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INTRODUCTION

Background

Many areas of Tennessee have been experiencing significant land development. Human activities, particularly urbanization and agriculture, can alter natural drainage patterns and/or add pollutants to rivers, lakes, and streams (See Figure 1). Typical pollutants in stormwater include elevated concentrations of sediment, oils and grease, heavy metals, salts, pesticides, nutrients, bacterial and other pollutants. Recent studies have shown that stormwater runoff is a significant source of water pollution, causing declines in aquatic health and restrictions on swimming, and limiting our ability to enjoy many of the other benefits that water provides (USEPA, 1992).

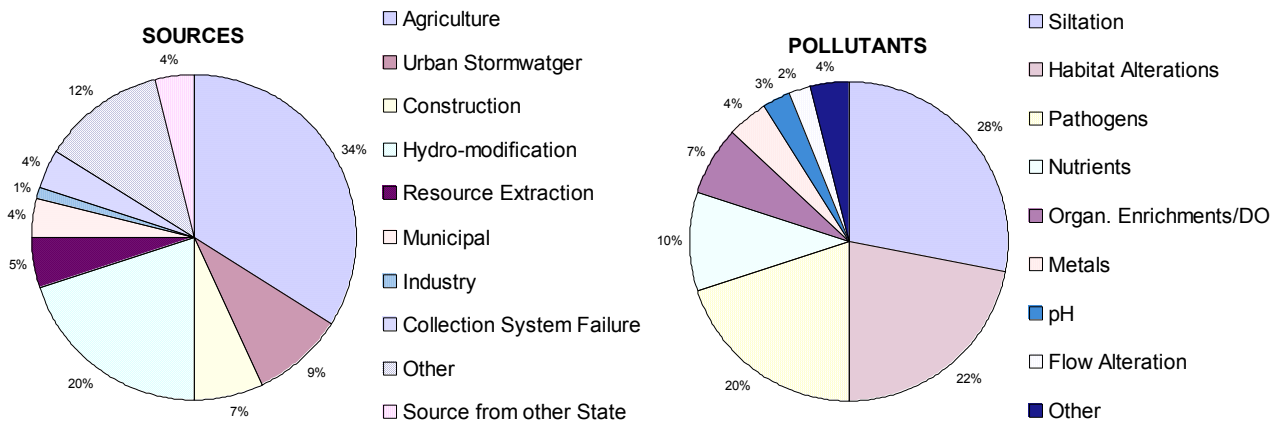

Figure 1. Relative Percentage of Pollutants and Sources for Rivers and Streams in Tennessee (Adapted from SWQT, 2000).

Much of this development can generally be characterized as urban (residential, commercial, industrial, and transportation) and greatly affects the way the developed land behaves hydrologically and environmentally. In addition to adding pollution, typical urban development increases both the quantity (volume) of stormwater runoff and the rate or concentration (peak flow) at which it enters receiving waters or flows to adjacent lands. The timing of this runoff is typically affected, also, and is capable of producing negative downstream consequences.

Many communities across Tennessee do not currently have the technical and regulatory tools, expertise and knowledge to ensure that local development progresses in a hydrologically and environmentally compatible manner. This manual has been developed to provide general guidance in developing and implementing the best management practices (BMPs) for inclusion in local municipal and county stormwater management programs. As mentioned elsewhere in this manual, federal regulations require municipalities to develop stormwater management programs to reduce the

discharge of pollutants to the maximum extent practicable (MEP). It is not the intent of this manual to dictate the actual selection of BMPs (this will be done by the municipality), but rather to provide the framework for an informed selection of BMPs for municipal programs. In selecting and implementing BMPs that will achieve MEP, it is important to remember that municipalities will be responsible to reduce the discharge of pollutants in stormwater to the maximum extent practicable. This means choosing effective BMPs, and rejecting BMPs that would not be technically feasible or be cost prohibitive. The following factors should be considered in deciding if a BMP is practicable:

1. Pollutant Removal – Will the BMP address the pollutant of concern?

2. Water Quantity – Will the BMP be an effective facility for managing and controlling water runoff flow and volume?

3. Regulatory Compliance – Is the BMP compatible with stormwater regulations as well as other regulations for air, hazardous wastes, solid waste disposal, etc.?

4. Public Acceptance – Does the BMP have public support?

5. Implementation – Is the BMP compatible with land uses, facilities, or development activity in question?

6. Cost – Will the cost for implementing the BMP exceed the pollution control and flow management benefits expected to be achieved?

7. Technical Feasibility – Is the BMP technically feasible considering soils, geography, water resources, maintenance and special site considerations?

For the BMPs selected, the municipality must demonstrate a "good faith" effort to implement and provide for long-term maintenance for them. Both publicly and privately-owned facilities require regular inspection and maintenance to ensue effective stormwater water quality and quantity management as intended by the designer. Finally, the municipality should prepare and adhere to a schedule for implementation.

Users of the Manual

The primary users of this manual are the municipalities and counties responsible for selecting BMPs as part of their overall stormwater management program. Such users include municipal engineers, public works officials, planners and environmental specialists. In addition, consulting/design engineers and developers will find the manual useful in their work.

Purpose and Scope of Manual

The purpose of this manual is to provide guidance to listed Phase II Tennessee stormwater program communities for selecting and implementing the best management practices (BMPs) for post-development activities. The BMPs presented in this manual are organized into *Non-structural* and *Structural* sections and are applicable to managing either or both water quality and quantity as shown in the matrix table below:

BMP	Symbol	Category	
		Water Quantity	Water Quality
NON-STRUCTURAL			
Comprehensive Planning, Zoning, Ordinances, and Codes	NS-01	X	X
Landscaping and Vegetative Control Practices	NS-02	X	X
Public Outreach and Education Awareness	NS-03	X	X
Good Housekeeping	NS-04		X
Urban Stormwater Pollution Prevention Plans	NS-05		X
Non stormwater Discharges to Storm Drains	NS-06		X
STRUCTURAL			
Detention (Dry) Basin	P-01	X	X
Retention (Wet) Basin	P-02	X	X
Alternative Storage Measures	P-03	X	X
Constructed Wetlands	W-01	X	X
Infiltration/Percolation Trench	I-01	X	
Infiltration Basin	I-02	X	X
Underground Drainage Systems	I-03		X
Porous Pavement	I-04	X	
Catch Basin Inserts/Media Filter	F-01		X
Oil/Water Separator	F-02		X
Filter and Buffer Strips	F-03	X	X
Filter/Adsorption Bed	F-04		X
Bioretention Basins (Rain Gardens)	F-05	X	X
Swale (Open Channel Systems)	O-01	X	X

Table 1. Matrix of structural and non-structural BMPs for water quality and water quantity management for applications intended for post-construction development.

Organization of the Manual

The overall goal of stormwater management is to reduce the discharge of pollutants while controlling the quantity of runoff from a development site. This manual is organized to assist the user in planning, developing, and implementing such a program. The manual contains the following elements, with applicable references:

- Forward - Basis and Context for Manual: Water Quality and Quantity Issues

- Background: Choosing BMPs, Purpose and Scope of Manual, Organization, Effects of Urbanization, including Sources and Effects of Pollutants
- Non-structural BMPs:
    - Description
    - Selection Criteria
- Structural BMPs:
    - Description
    - Selection Criteria
    - Design and Sizing Considerations
    - Construction /Inspection Considerations
    - Maintenance
    - Cost Considerations
    - Limitations of Use
    - Additional Information
    - References
    - Rating of targeted (pollutant) constituent benefits
        - Sediment
        - Heavy metals
        - Floatable materials
        - Oxygen demanding substances
        - Nutrients
        - Toxic materials
        - Oil & grease
        - Bacteria & viruses
        - Construction wastes
    - Rating of Implementation Requirements
        - Capital costs
        - O & M costs
        - Maintenance
        - Training

Effects of Urbanization

There are two main environmental impacts that typically result from urbanization. First, the hydrology of the area is changed. This change typically consists of increased runoff volumes, flows, and velocities, and reduced groundwater recharge. The timing of this runoff and base flow are also typically affected and may have negative downstream consequences. Second, urbanization increases a variety of human activities that generate pollutants within a watershed. The pollutants are transported in runoff and subsequently discharged to our streams and lakes. These activities may range from construction to automobile use to various types of private and public development and pedestrian uses after construction is completed.

Hydrologic Changes

When an undeveloped area changes to support urban land uses, dramatic impacts in the local hydrology result as illustrated in Figure 2. Urbanization typically changes the natural hydrology of a watershed through increased imperviousness,s thereby increasing direct runoff and decreasing evapotranspiration, deep infiltration, and shallow infiltration. When an area is developed, natural drainage patterns are modified as runoff is channeled into road gutters, culverts, storm drains, and paved channels. The results of these modifications typically produce an increase in runoff volume and velocity, and a shorter time for the runoff to leave the watershed, causing higher peak flows.

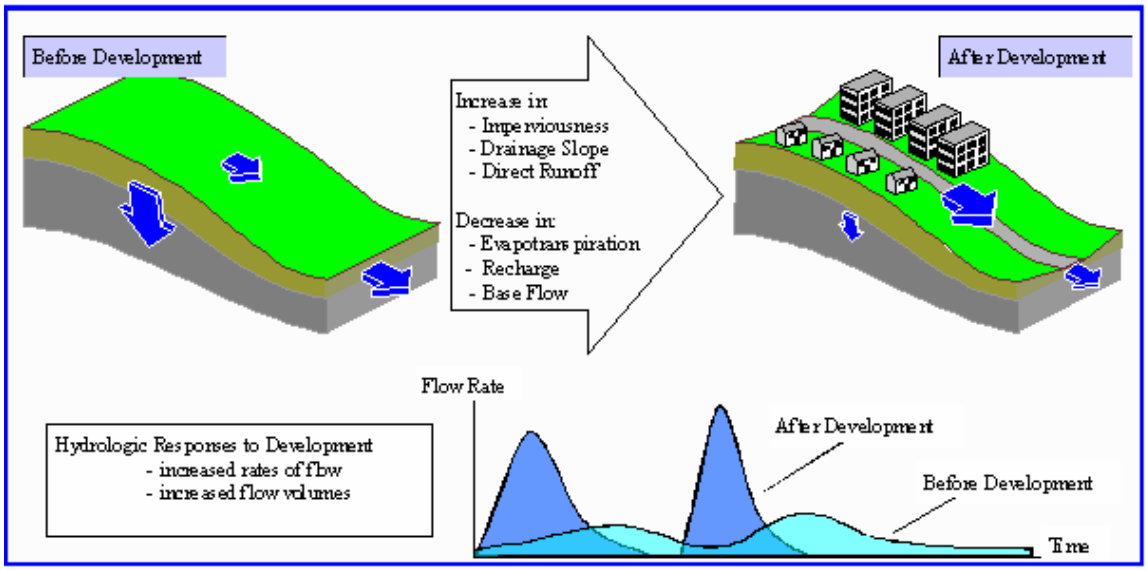

Figure 2. Changes in watershed hydrology resulting from urbanization.

In addition, higher flows can cause flooding and adverse effects on natural streams. Before development, at bankfull capacity, natural streams can handle a flow approximately equal to the 2-year frequency peak discharge. After development, this bankfull capacity can be exceeded several times per year. The new flow regime also can lead to channel and bank erosion and unwanted meandering and widening (Minnesota PCA, 1989).

The box below summarizes the typical impacts that urbanization has on both water quantity and water quality in water bodies such as lakes and streams.

Typical Effects of Urbanization

Hydrologic Changes

- Increased runoff volumes
- Reduced times of concentration for the contributing drainage areas, resulting in higher flow velocities and peak flows
- Increased frequency of flows for given storm events
- Decreased groundwater recharge
- Habitat destruction from flow changes, channel erosion, and channel improvements

Pollutant Generation

- Human activities create several types of biological, chemical and physical pollutants which are transported to receiving waters

Urban Storm Water Pollutants

Pollutants most frequently associated with stormwater include construction sediment and post-construction nutrients, bacteria, oxygen-demanding substances, oil and grease, heavy metals, other toxic chemicals (e.g., pesticides and herbicides), and floatables (e.g., fast-food litter and debris from traffic litter and fly away). In addition, urban runoff usually has a higher water temperature resulting from natural land being converted to paved areas and removal of stream shade.

Stormwater Pollutants of Concern

- Sediment
- Nutrients
- Bacteria and Viruses
- Oxygen Demanding Substances
- Oil and Grease
- Metals
- Toxic Pollutants
- Floatables
- (Increased) Temperature

These pollutants and their impacts on water quality and aquatic habitat are described as follows:

- *Sediment* is a common component of storm water and is a pollutant in its own right. Excessive erosion and sediment, especially generated during construction activities, can be detrimental to aquatic life (primary producers, benthonic invertebrates and fish) by interfering with photosynthesis, respiration, growth, and reproduction. In addition, the sediment can transport other pollutants that are attached to it including nutrients, trace metals, and hydrocarbons (AWPA, 1981). Sediment that leaves a site, whether during or after construction, has the potential for clogging downstream drainways, thereby reducing flow capacity, and causing flooding.

- *Nutrients* including nitrogen and phosphorous are found in stormwater. These nutrients can result in excessive or accelerated growth of vegetation or algae resulting in impaired use of water in streams, lakes and other water systems. In addition, un-ionized ammonia (one of the nitrogen forms) can be toxic to fish.

- *Oxygen demanding substances* including plant debris (such as leaves and lawn trimmings), animal excrement, street litter, and organic matter are commonly found in stormwater (USEPA, 1992; Woodward-Clyde, 1990). Such substances depress the dissolved oxygen levels in streams, lakes, and other water bodies, thereby depriving aquatic life of needed oxygen.

- *Oil and grease* contain a wide array of hydrocarbon compounds, some of which are toxic to aquatic organisms at low concentrations (Woodward-Clyde, 1990). The main sources of oil and grease are leakage from engines in parking lots and streets, spills at fueling stations, overfilled tanks, restaurant grease traps, and waste oil disposal (Berman, et al, 1991).

- *Lead, zinc, cadmium, and copper* are the most commonly occurring *heavy metals* in stormwater. Chromium and nickel are also frequently present (USEPA, 1983). Heavy metals are of concern because they are toxic to aquatic organisms, can be bio-cumulative, and have the potential to contaminate drinking water supplies.

- *Other toxic materials (priority pollutants)* may be found in stormwater in low concentrations. Pesticides, herbicides, phenols, and polynuclear or polycyclic aromatic hydrocarbons (PAHs) are the organics most frequently found in stormwater (City of Seattle, 1989).

- *Floatables* in stormwater are pollutants that may contain significant amounts of heavy metals, pesticides, and bacteria. Typically, resulting from street refuse, commercial areas, or industrial yards. Floatables also create "eyesores" along waterways, street inlets and in detention basins.

- *Temperature* of post-development runoff water tends to increase when natural land use areas are converted to paved or roofed areas. Also, water temperature in streams, formerly shaded with riparian trees and plants, tends to increase as the

vegetation is removed. Increased runoff temperature can be detrimental to aquatic life both on the development site as well as in downstream waterways.

Sources of Pollutants

The primary sources of stormwater pollution in urban areas include automobiles and activities associated with automobile use (including pavement), inadequate housekeeping and landscaping practices, industrial activities, construction, non-stormwater connections to the drainage system, accidental spills, and illegal dumping. Table 2 summarizes the relationship of pollutant sources with the pollutants they generate.

Pollutant	Automobile/Atmospheric Deposit	Urban Housekeeping/Landscaping Practices	Industrial Activities	Construction Activities	Non-stormwater Connections	Accidental Spills & Illegal Dumping
SEDIMENTS	X	X	X	X		
NUTRIENTS	X	X	X	X	X	X
BACTERIA & VIRUSES		X		X	X	X
OXYGEN DEMANDING SUBSTANCES		X	X	X	X	X
OIL & GREASE	X	X	X	X	X	X
Anti-freeze	X	X		X	X	X
Hydraulic fluids	X	X	X	X	X	X
Cleaners & solvents	X	X		X	X	X
HEAVY METALS	X	X	X	X	X	X
Chromium	X	X	X			
Copper	X	X	X			
Lead	X	X	X			
Zinc	X	X	X			
Iron	X		X			
Cadmium	X		X			
Nickel	X		X			
Manganese	X		X			
Paint		X		X	X	X
Wood preservatives		X		X	X	X
TOXIC MATERIALS	X	X	X	X	X	X
Fuels	X		X	X	X	X
PCBs	X				X	X
Pesticides	X	X	X	X	X	X
Herbicides	X		X	X	X	X
FLOATABLES		X	X	X		X

References: Minnesota PCA (1989); Berman, L., et al. (1991); Woodward-Clyde (1990); USEPA (1991); Schuler (1987); Beaton, J., et al. (1972); Camp Dresser & McKee (1993); and Oberts, G. (1986).

Table 2. Common Sources of Pollutants in Urban Stormwater Runoff

AUTOMOBILE AND RELATED ACTIVITIES

Sediment

Significant post-construction sediment-borne pollutants associated with highway and street runoff come from pavement wear, vehicles, atmospheric deposition, and road maintenance (USEPA, 1991). Atmospheric deposition contains appreciable quantities of sulfur, toxic and heavy metals, pesticides, organic compounds, fungi and pollen (Novatny and Chesters, 1981). Asbestos in runoff can occur from wear of clutch and brake linings (Berman, et al., 1991).

Accelerated erosion of highway slopes occurs primarily as sheet, gully, or rill erosion. Bridge construction may cause significant erosion and sedimentation (USEPA, 1991). Sand applied to icy roads can also create a significant sediment load.

Nutrients

Nitrogen and phosphorous associated with highway runoff come from atmospheric deposition and roadside fertilizer application (USEPA, 1991). Phosphorous has also been associated with application of sand and salt on roads (Oberts, 1986).

Heavy Metals and Toxic Chemicals

Several heavy metals and other toxic substances found in stormwater are associated with automobile use. Chromium, copper, lead, zinc, iron, cadmium, nickel, and manganese associated with automobiles and highways come from many different sources including auto body rust, bearing and bushing wear, brake lining wear, engine exhaust, metal plating, motor oil (stabilizing additives), steel highway structures (guard rails, lighting, signs, etc.), and tire wear (filler material). Other toxic pollutants occur primarily through the use of products for de-icing and weed, rodent, and insect control (Beaton, et al., 1972). Hydrocarbons typically come from spills, leaks or blow-by of motor lubricants, antifreeze and hydraulic fluids, and asphalt surface leachate. Hydrocarbon levels are highest from parking lots, roads, and service stations (Schueler, 1987).

Maintenance of transportation structures can result in runoff and direct discharge of lead, rust, paint, particulates, solvents, and cleaners. Runoff from bridges may deliver considerable loadings of heavy metals, hydrocarbons, and toxic substances from cars and de-icing of roads as a result of direct delivery through scupper drains into receiving waters with no overland buffering or treatment (USEPA, 1991).

URBAN HOUSEKEEPING/LANDSCAPING PRACTICES

Sediment

Landscape activities are a source of erosion and subsequent sedimentation, especially along street and road right-of-ways, residential areas and commercial districts.

Nutrients

In urban areas, major sources of nutrients are organic matter such as lawn clippings, leaves, street debris, and excessive use of fertilizers. Areas such as golf courses and cemeteries which receive unusually high fertilizer applications are major sources of nutrients (Schueler, 1987).

Bacteria and Viruses

Improper disposal of fecal material from household pets is a source of bacterial contamination (USEPA, 1991). Other sources include septic tanks and deposits of organic matter that accumulate and decompose in storm inlets, catch basins, storm drains, and drainage channels (Berman, et al., 1991). Sanitary sewer systems may also seep or overflow into the drainage system.

Oxygen Demanding Substances

In urban areas, plant debris (such as leaves and lawn-clippings), animal excrement, street litter, dead animals, and organic matter are common sources of oxygen demanding substances found in storm water (Minnesota PCA, 1989). Fast food garbage thrown along waysides also contributes.

Heavy Metals and Toxic Chemicals

Sources of heavy metals include weathered paint, wood preservatives, and pesticides (Woodward-Clyde, 1990). Excessive herbicide or pesticide use contributes toxic chemicals to the stormwater. Household toxics such as oil/grease, antifreeze, paint, household cleaners and solvents are widely used and may be improperly used, stored, and disposed of which can lead to stormwater pollution (Berman, et al., 1991). A national study of suburban stormwater showed few instances of detectable quantities of synthetic organic compounds, with the exception of plasticizing compounds often found in many plastic products. Also found, but less frequently, were wood preservatives sand pesticides (USEPA, 1983).

INDUSTRIAL ACTIVITIES

Trace metals (particularly chromium, copper, lead, and zinc) found in stormwater may come from industrial use (Woodward-Clyde, 1990). Pesticides, herbicides, solvents, oils

and other synthetic organic compounds are widely used in industrial settings and may be improperly stored and disposed, leading to contaminated runoff. While the BMPs discussed in this manual are intended for general municipal development activities, some may be applicable to industrial development.

CONSTRUCTION

Construction sites may generate considerable sediment, trace metals, nutrients, oil and grease, pesticides, herbicides, and other synthetic organic compounds. The user is referred to the Tennessee Erosion & Sediment Control Handbook (2002) for detailed construction best management practices.

NON-STORMWATER CONNECTIONS

Inadvertent or deliberate discharge of sanitary sewage and industrial waste to storm drains is a widespread and serious occurrence. Illicit connections of sanitary sewers to storm drain sewers (e.g., floor drains) are a source of storm water contamination.

ACCIDENTAL SPILLS AND ILLEGAL DUMPING

Deliberate dumping of chemicals into storm drains and catch basins (especially used crankcase oils) is a common source of pollutants (USEPA, 1991) and can be a local problem. Virtually any chemical, if not properly stored and handled, can be accidentally spilled or illegally dumped.

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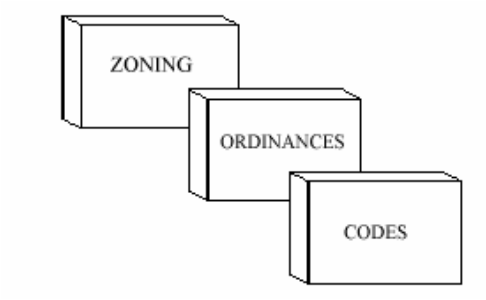
Non-Structural Best Management Practices (BMPs)

ACTIVITY: Comprehensive Planning, Zoning, Ordinances, and Codes

NS – 01



Description

The comprehensive planning process provides an opportunity to regulate certain land-use activities in areas where water quality and flooding are sensitive to development. All sites that are developed vary in their suitability for development. Typically, the function of the developed site is determined prior to construction, despite the environmental conditions (i.e., soil type, topography, natural landscape value, flood potential, drainage patterns, etc.). A comprehensive planning process can help develop the best procedures for addressing potential environmental problems while achieving compliance with human restrictions and needs.

Zoning, ordinances, and codes are mechanisms by which the comprehensive planning process can be regulated and provide assurance that the program has long-term stability. The purpose of zoning in a municipality is to foster a proper balance of land uses such that recreation, environmental conservation, and residential, commercial, and industrial development all can be achieved. Ordinances and codes are important to control both the quality and quantity of stormwater runoff from developed sites. Unless post-development stormwater runoff is controlled, discharge from developed sites can be detrimental not only to local streams, but to human welfare and safety as well.

Selection Criteria

Comprehensive planning and corresponding zoning, ordinances, and codes are perhaps more effective in controlling stormwater impacts in undeveloped rural and urban areas. Areas that have already been developed usually need to rely on expensive retrofit practices to comply with new regulations that accompany the implementation of a comprehensive planning program, whereas undeveloped areas can implement these practices into their original design. Although planning and regulations can be helpful in urbanized areas that are experiencing new development or redevelopment, the process is most successful and cost-effective if it is implemented before a majority of development has taken place.

Comprehensive Planning

Comprehensive planning is a detailed process that requires more than simply managing or treating a stormwater problem, it should involve a careful, well-thought-out, organized approach that is centered around the solution that can bring about sustainable development while providing longevity and ecological and economic amenities. The comprehensive planning process does not need to be complex, but should include the following steps or phases:

1. Identify the major short term and long term stormwater problems/issues.
2. Collect, review and comprehend all existing local, state, and federal governmental

or agency regulations, ordinances, codes, zoning requirements, permits, etc.

3. Determine objectives on how the site will be used, what site characteristics should be enhanced, what codes or restrictions should be addressed and develop clear-cut water quality and quantity goals.
4. Inventory the site resources (i.e., soil, water, air, vegetation, wildlife, etc.) and potential offsite impacts contributed to development through hydrologic and water quality studies and modeling.
5. Analyze the gathered resource information and quantify/qualify the site's resources and potential development impacts in order to prioritize the stormwater and environmental goals and estimate impacts of various structural BMPs.
6. Develop recommendations and alternative development strategies in order to address the identified stormwater objectives and goals. New zoning, ordinances, and/or codes can be proposed in this step that can help achieve the objectives and goals.
7. Present recommendations to a political body for acceptance and implementation.
8. Implement the recommendations and practices accepted by the local government within the developing community.
9. Conduct continuous evaluations of the plan through periodic inspections, monitoring, and revisions.

An important initial part of comprehensive site planning is to locate environmentally sensitive areas and assure that these locations are preserved. Critical areas, such as riparian zones, are areas that harbor ecologically valuable and sensitive water resources (i.e., wetlands, springs, seeps, streams, etc.). Buffer zones surrounding critical water resource areas can help reduce the impact of stormwater and should be preserved as well. Critical areas and their associated buffer zones require long-term protection that is typically provided in the form of zoning, ordinances, and codes. Both setback requirements and easements can also be effective tools in preserving critical water resources on a development site.

Zoning

Zoning is a land use control that dictates the type and density of development within a specific area. Proper zoning should allow for residential, commercial, and industrial development in an area, while still allowing for recreation, ecological conservation, and limited flood storage. Zoning should prevent or limit development in environmentally sensitive and critical areas and restrict land uses that pose a high potential for producing water pollutants. Zoning ordinances must be supported by a comprehensive planning process such that they are not used for pollution prevention purposes, which can be politically circumvented. (ASCE, 1998).

Stormwater Ordinances and Codes

Ordinances and codes are typically required to implement and enforce comprehensive plans and stormwater quality and quantity. A good stormwater ordinance should include, but is not limited to, the following aspects:

- Submittal and approval of a stormwater management plan for the proposed development that would explain the measures to address stormwater concerns
- Performance standards descriptions

- No net increase in the peak rate or volume of runoff after development based on design storms
- Control of first flush through the use of BMPs to remove majority of pollutants (i.e., sediment, hydrocarbons, metals, nutrients, etc.)
- Design and maintenance standards and permanent BMPs: the local government can include such standards, or refer to a separate resource or design manual containing detailed specifications. In addition, the government should define exemptions and size thresholds.
- Dedication of drainage easements to allow for proper maintenance of all control practices and structures.
- Prohibition of illicit connections or illegal discharges to the stormwater drainage systems or water bodies.
- Administrative and enforcement procedures which explains the permitting, inspection, enforcement, appeals and other administrative processes.
- Inspection of facility before releasing bond.

Local stormwater ordinances take many different forms. Some municipalities adopt separate stormwater ordinances, while others include their stormwater regulations within other land use ordinances such as subdivision regulations, erosion control, flood prevention, or watershed protection ordinances.

Local municipalities must adapt their stormwater ordinances to address water quantity and quality impacts. Public education is an important part of getting a stormwater ordinance passed. The public must understand and support the regulations and codes in order for the ordinance to be successful.

With the proper application of these comprehensive planning strategies and their corresponding enforcement mechanisms (zoning, ordinances, and codes), low-impact hydrologic objectives can be attained during the development process. The techniques discussed in this section can allow for the full utilization of a site while maintaining the predevelopment hydrologic conditions (i.e., peak flow, runoff volume, flood frequency, etc.) to the maximum extent possible. In addition to the preservation of pre-development hydrologic conditions, planning and regulation practices can reduce and even prevent water quality degradation that is associated with urban development, by providing for natural (i.e., vegetative buffer zones, infiltration) and structural (i.e., constructed wetlands, filter strips, adsorption beds, retention ponds, etc.) pollutant removal mechanisms.

The reader is referenced to the model stormwater ordinance contained in the Appendix of this manual.

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ACTIVITY: Landscaping and Vegetative Control Practices

NS – 02

Description

This non-structural best management practice is devoted to the use of permanent vegetation to ensure that water quality is not compromised after construction is completed. The preservation and planting of vegetation in and around stormwater management structures and BMPs can stabilize disturbed areas, enhance pollutant removal, and improve overall aesthetics. Landscaping of recently disturbed soil can greatly reduce erosion and sediment yield while providing some degree of dust control. Vegetative practices can also provide significant reductions in entrained pollutants through biological uptake, sediment trapping, filtering and infiltration.

Vegetation should also be controlled by a combination of proper mechanical and chemical (herbicides) means. Mechanical control measures include cutting vegetation less frequently, planting low-maintenance vegetation, such as vines and shrubs, collecting and properly disposing of clippings and cuttings, and education of the public and public works employees. The primary goal of this practice is to either establish temporary and/or permanent vegetative cover or preserve existing vegetation to lower runoff volumes and rates while greatly improving the water quality of urban stormwater runoff. Although a landscaping and vegetative control program is an integral part of any land development plan, it may be part of, but should not replace a stormwater management program. The reader is referenced to the *Tennessee Erosion and Sediment Control Handbook* for more information on these vegetative control practices.

Selection Criteria

Landscaping and vegetative control practices are applicable to all land uses, yet the selection of appropriate vegetation is dependant upon the soil, topography, and climate of the area. These factors also dictate what time of year the vegetation is planted or how often control measures need to be conducted. The following areas are important targets for landscaping and vegetative control practices:

- Steep slopes
- Drainage channels with natural cover
- Creeks
- Areas adjacent to catch basins
- Buffer zones
- BMP's such as detention/retention ponds, wetlands, swales and infiltration devices
- Construction sites. Temporary landscaping should be performed on areas such as construction sites, which will be denuded for several weeks.

- Permanent landscaping and control practices should be applied on all areas that have an established grade or require a long-term cover of vegetation such as filter strips, vegetated swales, steep slopes, stream banks, etc.

The main practices described herein include: buffer zones, disturbed area stabilization with mulch, disturbed area stabilization with permanent vegetation, disturbed area stabilization with sod, erosion control blanket/matting, and bioengineered stream bank stabilization.

In addition, components of a landscaping plan and the six zones of vegetative planting are discussed in this BMP.

Buffer Zones

A buffer zone is a strip of undisturbed vegetation, enhanced or restored vegetation, or the re-establishment of vegetation surrounding an area of disturbance or bordering streams, ponds, wetlands, or lakes. A buffer zone provides a filter for runoff and debris and a transitional refuge for small animals. There are two types of buffer zones: general buffers and vegetated riparian buffers. The former is a strip of undisturbed land adjacent to a site, while the latter borders a stream. To preserve natural vegetation, careful planning is required prior to construction such that contours and hydraulic characteristics are maintained wherever possible.

The important factors concerning the design of a buffer zone include slope, hydraulic characteristics, hydrology, and the width and vegetative structure of the zone.

It is important that the condition of the buffer is maintained. This includes monitoring the welfare of the vegetation with respect to climate and animals, such as beavers.

Disturbed Area Stabilization with Mulch

Mulching is the practice of covering a disturbed soil surface with biodegradable or other suitable materials for the purpose of stabilizing the soil surface. This practice is a common temporary stabilization technique, but is also effective as a permanent means. Some common permanent mulches include hardwood mulches and pine straw. This practice is simple and cost-effective.

Although mulches are best suited for flatter areas, they may be anchored to steeper areas with nets, mats, or tackifiers.

It is important to ensure proper coverage and depth of mulch to maximize its stabilization and moisture retaining effects. Inspect mulch after rainstorms and periods of high winds to check for movement. In addition, reapplication of mulch is necessary as the mulch degrades.

Disturbed Area Stabilization with Permanent Seeding

This practice involves the planting of perennial grasses for permanent stabilization. Vegetative cover is the most economical means of controlling erosion. Permanent seeding is used on exposed soils that will not be regraded, and where there is a proper

depth of topsoil. Permanent seeding is desirable on aesthetically critical areas.

Care should be taken to ensure development of permanent vegetation. Site conditions, such as soil types, exposure to wind and direct sunlight, and soil drainage must be considered when deciding types of vegetation. The earth on site should be properly prepared for vegetative growth. The top soil should have a minimum compacted depth of 2 inches on 3:1 slopes or greater, and 4 inches on all other slopes. Low maintenance local plant species should be used and mulching should be applied to slopes of 4:1 or greater. Fertilization and irrigation may be required, and should be provided in the design. Channelized flow should be directed away from the seeded areas and heavy clay or organic soils should be avoided as topsoil for all permanent vegetation. Newly vegetated areas should be inspected following each rain to ensure that seed has not been displaced. Also, the plants should be inspected frequently during the first year of planting to ensure uniform and dense stands.

Disturbed Area Stabilization with Trees, Shrubs, Vines, and Ground Cover

This practice involves the planting of Trees, shrubs, vines and ground cover for permanent stabilization, erosion control, reduced runoff, and enhanced aesthetics and wildlife habitat.

This vegetation is applicable for areas where grass does not grow well, such as steep slopes, shady areas and rough terrain. In addition, sites that are difficult to maintain grass, and where shade and screening are desired are often ideal areas for trees, shrubs, vines, and ground cover.

Selection of a species is based on site characteristics, such as amount of sunlight, drainage, and soil types. Low maintenance local plant species with a proven track record should be used, and mulching should be applied on slopes of 4:1 or greater. Often, the site can be altered to accommodate the desired plant type. In either case, it is necessary to ensure proper installation, including fertilization and appropriate planting depth. Fertilization and irrigation may be required, and should be provided in the design. Before performing work, the contractor should furnish proof that a nursery dealer's certificate has been secured with each shipment of plants.

Top soil with low amounts of heavy clays and organic matter should be spread to a minimum compacted depth of 2 inches on 3:1 slopes or greater, and 4 inches on all other slopes. Channelized flow should be directed away from the seeded areas.

Maintenance of the vegetation is just as important; irrigation, fertilization, and mulching should be provided for the plants. Different plant varieties require different maintenance, so care must be taken to yield optimum growth. Newly vegetated areas should be inspected following each rain to ensure that seed has not been displaced. Also, the plants should be inspected frequently during the first year of planting to ensure uniform and dense stands.

Sodding

This practice involves the import of sod to a site as a means of providing a quick, protective ground cover. It is used in areas susceptible to erosion, such as steep slopes, and drainage ways, at sites where immediate permanent ground cover is warranted, and

in areas where the season is not favorable for proper seed establishment. Adequate preparation measures must be taken for sodding operations. This includes proper soil preparation and provisions for watering the freshly laid sod at the required intervals. The type and depth of top soil and maintenance provisions are similar to that

of permanent seeding. In addition, the sod must be certified by the State Department of Agriculture prior to removal for sale or movement. See the *Tennessee Erosion and Sediment Control Handbook* for more information. It is important that sod is laid properly and is properly staked when laid on slopes.

Erosion Control Matting

This is the practice of placing a non-degradable protective matting to assist in the establishment of permanent vegetation on slopes, channels or other critical areas. Normally, the main objective of erosion control matting is to provide a stable seedbed for one or more growing seasons.

The areas where the mats are used need to be previously shaped, fertilized, and seeded, as directed by the engineer. The mats need to be installed correctly, using approved materials and techniques. In addition, the mat must be appropriate for the site conditions.

The mats should be inspected regularly for movement and condition of the matting, topsoil, and mulch. If washout, breakage, or erosion occurs, repair the surface and vegetate. Continue inspections until vegetation is firmly established.

Biotechnical Stream Bank Stabilization

As the title suggests, this process entails the use of mechanical elements (or structures) in combination with biological elements (or plants) to prevent slope failures and erosion, trap sediment, provide wildlife habitat, and enhance aesthetics.

Successful implementation of biotechnical stream bank stabilization involves the employment of various BMPs listed in this manual and the *Tennessee Erosion and Sediment Control Handbook* as well as competent knowledge of engineering and horticulture. Also, proper permitting from such regulating agencies as the NRCS, Tennessee Division of Water Pollution Control, and/or the United States Army Corps of Engineers may be required. For more information, see http://www.state.tn.us/environment/permits/arap.htm.

Once installed, the system should be inspected for proper vegetation growth and structural stability. Any deficiencies of the system should be repaired immediately.

The Landscaping Plan

The landscaping plan depends upon the BMP being applied, but the following are some key components that can assure success to any landscape plan:

- Proper plant species selection
- Transport and storage of plant material
- Sequence of construction

- Installation of plant material
- Contractor responsibilities
- Maintenance

Planting Zones

For landscaping of BMPs such as detention/retention ponds and constructed wetlands various planting zones exist within the structure representing a different soil moisture and inundation frequency. These zones are illustrated in Figure NS-02-1. The various planting zones can be classified as follows:

- Zone1: Deep Water Zone - This zone is typically only found in retention ponds, wetlands, and extended detention ponds due to a submergence of 18 inches to 6 feet. Submerged aquatic vegetation such as pondweed and wild celery can flourish here and actively remove metals and nutrients from the water.
- Zone 2: Shallow Water Areas - This zone is 0 to 18 inches below normal depth and divided into low marsh (6" to 18"deep) and high marsh (0 to 6" deep) sub-zones. The vegetation in this zone can enhance nutrient uptake, reduce flow velocity, reduce resuspension of bottom sediment, provides habitat, reduces shoreline erosion, and improves aesthetics.
- Zone 3: Shoreline Fringe: - This zone is routinely inundated during runoff producing events and may remain saturated by proximity of normal pool. Because of dry weather periods, the plants of this zone must be tolerant of periodic drying. For retention ponds and wetlands this zone extends 1 foot above the normal pool level and for extended detention ponds, it continues up to the elevation of maximum volume. The Zone 3 vegetation consists mostly of the herbaceous variety such as pickerelweed, and rice cutgrass but can also include trees such a willows and shrubs (although trees and shrubs should not be planted on embankments). Zone 3 landscaping stabilizes the shoreline, improves aesthetics, limits shoreline access be people and animals, provides food, cover and nesting for wildlife.
- Zone 4: Riparian Fringe - This is the lower basin areas of detention ponds and the upper storage areas of extended detention ponds and is only briefly inundated during storms. Vegetation in this zone include willows, river birch, red chokeberry and can reduce resuspension of deposited sediment, prevent erosion and provide habitat and food for wildlife.
- Zone 5: Floodplain Terrace - This zone is only inundated during large storms and is generally between the 2-year and 100-year water surface elevations. Plant species in this zone should be native to floodplains and should be able to provide erosion control on steep slopes, survive periodic mowing, require minimal maintenance, and be able to withstand exposure and compacted soil.

- Zone 6: Upland Slopes - This zone seldom, if ever, experiences inundation and typically includes any required buffer areas. The plant species in this zone depend upon local soil conditions and the intended secondary uses of the area.

Timely and properly landscaping of disturbed areas and applying vegetative control practices to existing plant life can many positive water quality and quantity impacts on a watershed. The water quantity advantages include reduction of runoff volume through enhanced interception and infiltration and peak flow reduction by reducing stormwater velocities. The positive impacts of landscaping and vegetative controls on water quality include, but are not limited to, erosion and dust control, streambank and slope stabilization, and enhanced removal of urban pollutants. In addition to these water quantity and quality amenities, landscaping and vegetative control practices improve aesthetics of a watershed, can provide habitat for wildlife, and can cost effectively enhance the performance of structural BMPs. Under no circumstance, however, should trees or other deep rooting vegetation be planted on detention dam embankments that could negatively affect the stability of the structures or hinder inspection and maintenance.

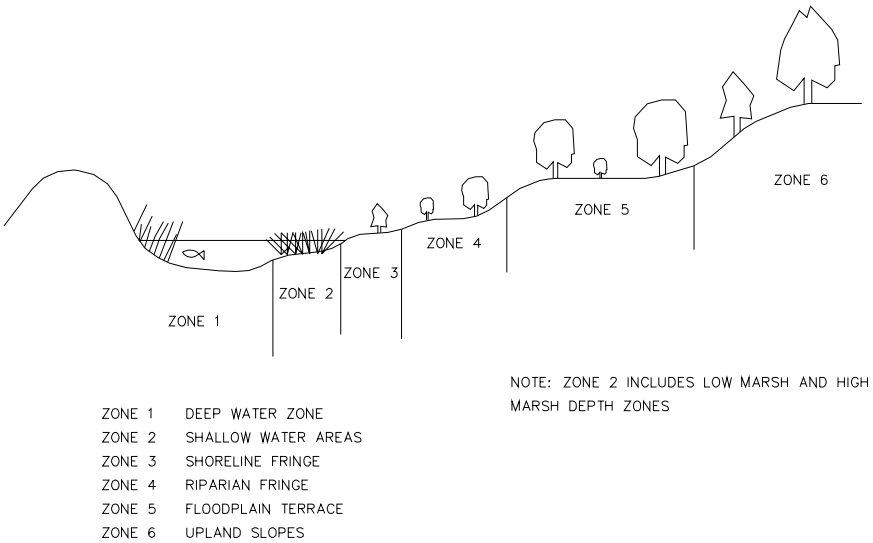

Figure NS-02-1 – Planting Zones

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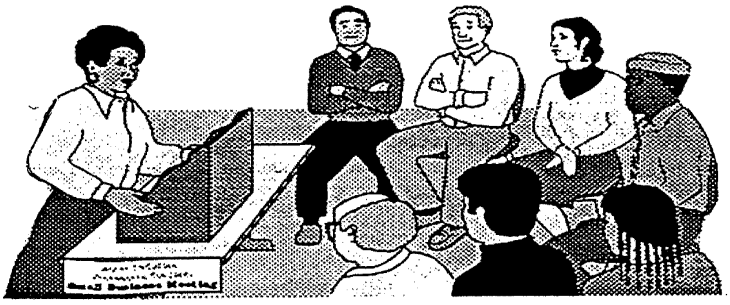
ACTIVITY: Public Outreach and Education

NS – 03



Description

As the demands of the NPDES permitting and its corresponding source control philosophy become more prominent across the nation, the need for public awareness and education is becoming vitally important. In order for the implementation of a successful urban stormwater management program, there must be an interaction with and education of the public from the program's inception as well as throughout its service life. This program needs to address the importance of having a stormwater management plan and reveal the potential repercussions of not having a functional program.

Stormwater education starts with a well-thought-out and well-developed outreach plan to make the public aware of the problem of stormwater pollution and ways they can help to prevent it. The outreach plan should identify goals and objectives, classify the target audience, identify the message to be conveyed, and explain how the message will be distributed to the audience.

Selection Criteria

The first step is to determine the goal and objectives of the outreach plan. The long-term goal should be set before the appropriate steps can be taken to accomplish that goal.

Depending upon the goals that a particular municipality has in mind, there are some general objectives that can be developed. First of all, it is important inform and educate the stakeholders and the public about:

- Stormwater management programs and needs
- The Federal stormwater quality regulations and requirements
- Stormwater management program costs and financing alternatives (emphasis on stormwater utility)
- The direction and projected growth of the program.

The next step is determining the target audience. It is important to keep in mind that different sectors of the "public" will take part in or be interested in very different issues and stages of the program:

- The environmental community will be vitally interested in water quality issues;
- School children can be interested in the environment or creek clean-up projects;

- Social classes may be interested in utility fees or charges;
- Tax exempt and governmental properties will be interested in fees or charges;
- The developers will be very interested in regulatory and economic aspects;
- Specific neighborhoods will be interested in special provisions for drainage controls, safety, greenways, etc.;
- Design professionals will have an interest in the technical criteria and regulatory requirements; and
- Commercial and industrial concerns may deal with fees and charges/credits.

Public outreach and education programs often need to be conducted and tailored to address a wide range of very different audiences, each with their own special interests and needs.

After determining the target audience, the next step is deciding how to reach it. If there is more than one audience to address, can they be reached simultaneously or should they be prioritized? This will depend on the type(s) of audiences to be reached and the message(s). Once the target audience(s) has/have been determined and the stormwater message has been packaged, distribution can begin. Outreach materials (posters, flyers, magnets, etc.) will not help prevent stormwater pollution if the target audience does not receive, read, and understand them. Common distribution mechanisms include direct mail, door-to-door distribution, telephone, targeted businesses, presentations, handouts at events, media outlets, and messages posted in public places. Deciding how to distribute materials involves a close look at the level of time, resources, and work required. For example, if posters with a stormwater message are to be printed, several things need to be decided: Should the posters be mailed to a specific audience? Should mailing tubes be purchased? Are addresses available?

Outreach and education can be implemented in several ways. It is not always necessary that the entire audience be reached at once. Therefore, one or more of the following approaches might be useful.

Signage and Storm Drain Stenciling

This procedure has been successful in many parts of the country. The idea is to remind the public of the function of storm drain appurtenances to prevent their misuse.

Mail

The mail delivery system can be the best distribution vehicle if the target audience can be defined geographically or if a mailing list that encompasses the entire audience (e.g., landscapers, farmers, garages) is accessible. The U.S. Postal Service has established procedures for bulk mailings, and it is advisable to contact the post office early to discuss the pros and cons of this delivery approach. In addition, lightweight flyers and brochures can be added to general mailings, such as utility bills or notices

about municipal services, without raising the cost of postage.

Door to Door

Door-to-door canvassing is very effective, but it is resource-intensive if employees are required to deliver the items. If it is too difficult or expensive to send employees door-to-door, it might be possible to work with local scout troops, environmental groups, or other organizations that are willing to canvass or deliver the message. A recommended approach is to print door hangers with the message that can be distributed without disturbing the occupants.

Businesses, Organizations, and Public Places

Using selected businesses and organizations to deliver the message can increase the likelihood of reaching the target audience and save money on postage. For example, if a brochure or poster on oil recycling is printed, the brochure/poster could be displayed at auto parts supply outlets. Lawn and garden centers could display an alternative lawn care poster. Businesses will be more likely to distribute materials if there is an added benefit to them. "Green company" endorsements could be included on the posters. Septic tank pumpers could be asked to distribute refrigerator magnets containing information on proper septic tank care and include a space on the magnet for the customer to write down the pumper's name and phone number. Schools and local organizations with building space are good candidates for the display of materials, especially posters.

Presentations

Presenting the message directly can be a very effective way to reach the target audience. The audience should be allowed the opportunity to ask questions, and any questions should be responded to immediately. Presentations can be given at events tailored to the audience, such as schools, retirement homes, local clubs, libraries, businesses, and associations.

Conferences

Conferences can be an excellent way to distribute messages through presentations, promotional give-aways, and displays. However, a conference might not reach all of the intended audience, and those who attend might already be familiar with the message and its significance.

Media

Messages that are recorded either in audio or video can be played on local radio or cable stations, particularly if they are required to make public services announcements. Sometimes the easiest way to distribute a message is to have someone else do it. If the target audience subscribes to an existing periodical, it might be more effective to include the message in that publication. It will certainly save time, instead of dealing with mailing lists, postage costs, or news media releases. It also increases the likelihood that the message will actually be read by members of the target audience since they are already familiar with the publication. Brochures and flyers can also be displayed in local libraries and other public buildings.

Internet

An internet website is a good way of educating the public because an unlimited amount of information can be displayed there. In addition, the website can be interactive, allowing a more hands-on approach to learning than other forms of media. Drawbacks include advertising and construction of the website.

The effectiveness of distributing storm water materials depends on many factors. These include:

- The costs associated with designing, producing, and distributing materials
- The type of audience to receive the message and what the audience does with the materials.
- The quality of the materials also plays a role in the message's effectiveness. It is important that a brochure be carefully prepared to ensure that it is actually read. Another approach is to convey a message in a simple form, such as a magnet. A magnet posted on a refrigerator at home is likely to be more effective than a flyer that is wordy or complicated.
- Benefits to using storm water outreach material are that they can reach a large audience. If the slogans, graphics, and other aspects of the materials are catchy, the messages will be even more effective.

Next, there needs to be input gathered from the stakeholders and public on the following:

- Desired stormwater management program direction, activities and structure
- Existing stormwater problems and future needs
- Willingness to pay for the program.

Once the public input is compiled, the stakeholders and public must be involved in the development of the program through:

- Meetings with stakeholders and other groups
- The use of public hearings
- A citizen task force
- The use of special events.

Through the public input and involvement, it is then necessary to gain a general consensus for the proposed stormwater management plan and program as well as the

creation of a stormwater utility. Once the stormwater plan is implemented, the public education program needs to be monitored in the following ways:

- Monitoring all forms of media to keep track of public opinion
- Obtain feedback through a hotline and/or all public events
- Measuring the public acceptance of the overall program.

Stormwater quality can be greatly improved by simply educating the public on issues such as the fact that water or any other fluid or item that enters the storm sewer system via culverts, catch basins, etc., typically does not get treated before discharging into the same stream, river or lake that they rely on for recreation, and/or water supply. In addition, explaining that litter and debris can clog drainage systems and accelerate flooding, can lead to reduction in property damage and potential loss of life associated with urban flooding. In regard to water quantity, educating developers on the adverse effects of impervious areas (especially directly connected impervious areas) and the numerous benefits of green space, trees, porous pavement, infiltration, etc. can lead to the reduction of peak runoff rates and volumes.

Limitations

Limitations to outreach materials are mainly associated with the time and cost of making and distributing the materials. Other barriers are the types of audiences to reach; for example, various age groups might need to be addressed separately.

The cost of distributing storm water messages depends on the method used and what is to be distributed. The U.S. Postal Service bulk mail has specific requirements, but discounted unit costs. Going door-to-door can be labor-intensive and requires staff or volunteers and transportation. Using businesses to distribute the message can be very effective and requires virtually no distribution cost. Electronic presentations (e.g., in Microsoft PowerPoint) can be a less expensive way to present information if computers and projectors are available for use or loan. Presentations can be costly, depending on the materials. Flip charts and posters can cost $5.00 each or more. Producing 35-mm slides (from slide film or computer disc) costs approximately $4.00 per slide.

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ACTIVITY: Good Housekeeping

NS – 04

Description

Good housekeeping consists of best management practices (BMP) utilized to control pollutant discharges, and to ensure that the BMP functions according to the designer's intentions. Common pollutants include automotive fluids, paints, pesticides, herbicides, litter, cement, and yard wastes. The objectives are to keep rain from contacting pollutants and to keep storm conveyance structures from coming into contact with pollutants. Proper maintenance and repair of existing drainage systems will greatly improve water quality and allows the storm drainage system to function at peak levels and reduce flooding. Properly designed catch basins and detention basins allow for easy removal of accumulated sediments at relatively minor cost.

Selection Criteria

Some of the most considerable nonpoint source pollution impacts in urban areas are a direct result of littering, collection of debris, deposition of contaminants, and improper waste disposal on roadways and parking lots. As a result of this pollution, stormwater catch basins become affected with debris and contaminants that have washed off of the roads and parking lots, which can lead to flooding and/or contamination of receiving waters.

Selection of these measures depends on the maintained area. Common BMPs involved in housekeeping processes include pavement cleaning, catch basin cleaning, litter control, waste disposal, materials storage, training, and equipment / vehicle cleaning.

Pavement Cleaning

This management measure involves employing pavement cleaning practices such as street sweeping on a regular basis to minimize pollutant export to receiving waters. These cleaning practices are designed to remove from road and parking lot surfaces sediment debris and other pollutants that are a potential source of pollution impacting urban waterways.

In particular, urban municipalities with a central gathering/metropolitan district, athletic/concert stadiums or arenas, fairgrounds, or shopping malls should be especially interested in the benefits of street and catch basin cleaning because of the high potential for the intense volume of accumulated debris and contaminants following special events and daily activities. Areas with high traffic volumes should also be targeted because of atmospheric deposition of exhaust emissions and litter that is thrown from automobile drivers and/or passengers. The street cleaning should focus on, but not be limited to, those roadways that border urban streams and most parking lots.

It should be stressed that street cleaning that involves washing down the road or

parking lot does not improve the situation and can actually make the pollution problem worse. Street washing actually induces the movement of debris and other contaminants towards and into the storm drain network, rather than removing the pollutants from the urban surfaces. Any cleaning procedure necessarily involves gathering and properly disposing of pollutants.

Following are some additional notes on this practice:

- Sweep parking lots and other paved areas periodically to remove debris. Dispose of debris in the garbage.
- If outdoor pavement cleaning with detergent is required, collect wash water and dispose in indoor sinks or drains for discharge to the sanitary sewer. Contact your local wastewater treatment agency.
- Use the most sophisticated sweepers available. Innovations in sweeper technology have improved the performance of these machines at removing finer sediment particles, especially for machines that use vacuum-assisted dry sweeping to remove particulate matter. By using the most sophisticated sweepers in areas with the highest pollutant loads, greater reductions in sediment and accompanied pollutants can be realized.
- Regulate parking. The ability to impose parking regulations in densely populated areas and on heavily traveled roads is essential.
- The frequency and location of street sweeping is another consideration for any program. This is usually determined by the program budget and the desired level of pollutant removal. In turn, this will be a governing factor of the number of street sweepers required.
- Street cleaning twice a week has been found effective in removing a large portion of floatable pollutants from urban roadways and parking lots.
- Street cleaning programs require a significant investment of capital and a yearly operation and maintenance budget. The operation and maintenance costs for two types of sweepers are included in Table NS-04-1.

Table NS-04-1

Estimated costs for two types of street sweepers

Sweeper Type	Life (Years)	Purchase Price ($)	O&M Cost ($/curb mile)	Sources
Mechanical	5	75,000	30	Finley, 1996 SWRPC, 1991
Vacuum-assisted	8	150,000	15	Finley, 1996 Satterfield, 1991

Limitations to pavement cleaning include the high cost of current sweeper technologies, the potential inability to restrict parking in urban areas, the need for sweeper operator training, and the lack of solid evidence regarding the expected levels of pollutant removal. Proper disposal of swept materials might also be a limitation.

A benefit of street sweeping is that it is a preventative measure. By capturing pollutants before they are made soluble by rainwater, the need for structural storm water control measures might be reduced. Structural controls often require costly added measures, such as adding filters to remove some of these pollutants and requiring regular manpower to change-out filters. Street sweepers that can show a significant level of sediment removal efficiency may prove to be more cost-effective than certain structural controls, especially in more urbanized areas with greater areas of pavement.

Catch Basin Cleaning

Routine cleaning of catch basins can limit the amount of collected sediment and debris from entering and potentially clogging the storm drain network or ultimately discharging into downstream waterways. In general, by preventing the entrainment of pollutants in stormwater runoff through catch basin cleaning, flooding problems due to the clogging of storm drain networks and the nonpoint source contamination of receiving waters can be greatly reduced.

Litter Control

This practice involves the reduction of intentional littering. Litter is often washed into storm structures and streams before it can be gathered and disposed properly.

Examples of effective programs and practices to reduce and control litter are as follows:

- Provide an adequate number of trash receptacles for your customers and employees. This helps keep trash from overflowing the receptacles.
- Empty full trash receptacles immediately. This keeps trash from accumulating around the receptacle and being dispersed.
- Pick up litter and other wastes daily from outside areas including storm drain inlet grates.
- Post signs along roads and in public areas reminding of the penalty involved for littering. This will reduce the amount of purposeful littering.
- Organize frequent “Clean-up Days”. This promotes good-feeling around the community and allows for a survey of the condition of existing storm structures.

Limitations to litter control include the allocation of man-hours to accomplish this task. Picking up trash needs to become a job for the entire community.

A benefit of litter control is that it is a preventative measure. By gathering litter before it is carried away by surface runoff, clogging of storm drain structures can be prevented.

Waste Disposal

This practice involves the proper disposal of waste products. Often, wastes are carelessly disposed in areas that affect the local streams.

Programs to control waste should promote the following practices:

- Inspect dumpsters and other waste containers periodically. Repair or replace leaky dumpsters and containers.
- Cover dumpsters and other waste containers.
- Never dispose of waste products in storm drain inlets.
- Recycle wastes or dispose properly.
- Do not dispose of waste products in unapproved areas, such as sinkholes.

Limitations to waste disposal include the inconvenience of transporting wastes to proper disposal sites. Another limitation is lack of education in the community of the effects of wastes on the watershed.

A benefit of proper waste disposal is that it is a preventative measure that can lead to increased water quality in the watershed.

Materials Storage

Improperly stored materials can have a dramatic impact on local waterways. Soluble materials exposed to rain or surface water will affect water quality.
Covering hazardous materials and areas where such materials are handled reduces potential contact with storm water and wind. Storage areas, outdoor material deposits, loading and unloading areas, and raw materials should all be covered or enclosed. Priority should be given to locations of the most hazardous substances.

Maintenance of hazardous material storage areas consists mostly of inspection and employee training. Storage spaces and containers should be routinely inspected for leaks, signs of cracks or deterioration, or any other signs of release.

Some practices to control hazardous materials are given as follows:

- Store materials such as grease, paints, detergents, metals, and raw materials in appropriate, labeled containers.
- Store household hazardous wastes until they can be disposed properly.
- Make sure all outdoor storage containers have lids, and that the lids are adequately closed.
- Store stockpiled materials inside a building, under a roof, or covered with a tarp to prevent contact with rain.
- Ensure sufficient aisle space to provide access for inspections and to improve the ease of material transport.
- Store materials well away from high-traffic areas to reduce the likelihood of accidents that might cause spills or damage to drums, bags, or containers.

- Stack containers in accordance with the manufacturers' directions to avoid damaging the container or the product itself.
- Store containers on pallets or equivalent structures. This facilitates inspection for leaks and prevents the containers from coming into contact with wet floors, which can cause corrosion. This consideration also reduces the incidence of damage by pests (insects, rodents, etc.).
- Delegate the responsibility for management of hazardous materials to personnel trained and experienced in hazardous substance management.

Training

In-house employee training programs are established to teach employees about storm water management, potential sources of contaminants, and BMPs. Employee training programs should instill in all personnel a thorough understanding of their Storm Water Pollution Prevention Plan (SWPPP), including BMPs, processes and materials they are working with, safety hazards, practices for preventing discharges, and procedures for responding quickly and properly to toxic and hazardous material incidents. Training on storm water management and BMPs can be incorporated into these programs. Employees can be taught through 1) posters, employee meetings, courses, and bulletin boards about storm water management, potential contaminant sources, and prevention of contamination in surface water runoff, and 2) field training programs that show areas of potential storm water contamination and associated pollutants, followed by a discussion of site-specific BMPs by trained personnel.

Effective elements of employee training involve programs to:

- Training employees regularly on good housekeeping practices.
- Assigning a person to be responsible for effective implementation of BMPs.
- Promoting a clear identification and understanding of the problem, including activities with the potential to pollute stormwater.
- Identifying solutions using BMPs and available technologies.
- Ensuring strong commitment and periodic input from senior management. Communicating frequently to ensure adequate understanding of SWPPP goals and objectives.
- Utilizing experience from past spills to prevent future spills.
- Making employees aware of BMP monitoring and spill reporting procedures.
- Developing operating manuals and standard procedures.

Obstacles to an employee training program include: Lack of commitment from senior management; Lack of employee motivation; Lack of incentive to become involved in BMP implementation.

Advantages of an employee training program are that the program can be a low-cost and easily implementable storm water management BMP. A training program is also flexible and can be adapted as a facility's storm water management needs change over

time.

Equipment/Vehicle Cleaning

Outdoor car washing has the potential to result in high loads of nutrients, metals, and hydrocarbons during dry weather conditions in many watersheds, as the detergent-rich water used to wash the grime off of cars flows down the street and into the storm drain.

Pollution from vehicles can be reduced in the following ways:

- Maintain equipment and vehicles regularly. Check for and fix leaks.
- Use drip pans to collect leaks or spills during maintenance activities.
- Wash equipment/vehicles in a designated and/or covered area where the wash water is collected to be recycled or discharged to the sanitary sewer. Contact your local wastewater treatment agency.
- Wash cars on gravel, grass, or other permeable surfaces.
- Block off the storm drain or using an insert to catch wash water.
- Pump soapy water from car washes into a sanitary sewer drain.
- If pumping into a drain is not feasible, pump car wash water onto grass or landscaping to provide filtration.
- Use hoses with nozzles that automatically turn off when left unattended.
- Use only biodegradable soaps.
- All vehicle washing should be done in areas designed to collect and hold the wash and rinse water or effluent generated. Wash water effluent should be recycled, collected, or treated prior to discharge to the sanitary sewer system.
- Pressure cleaning and steam cleaning should be done off-site to avoid generating runoff with high pollutant concentrations. If done on-site, no pressure cleaning and steam cleaning should be done in areas designated as wellhead protection areas for public water supply.
- On-site storm drain locations should be mapped to avoid discharges to the storm drain system.
- Spills should be immediately contained and treated.

The biggest limitation to implementing residential car wash best management practices may be the lack of knowledge regarding the impacts of polluted runoff. Another limitation is the inconvenience of proper disposal of vehicle wash water.

Staffing and materials represent the largest expenditure for local governments seeking to administer a nonpoint source education program. Car wash outreach programs are relatively inexpensive to staff and often require only a limited outlay for materials (brochures, training videos, etc.), and staff time devoted specifically to car wash

water containment equipment is often a one-time expense, and this equipment is often used for a number of years.

Routine housekeeping measures, in all urban settings, can reduce the amount of floatable litter and contaminants that would otherwise be entrained in runoff and discharge to receiving waters or clog the drainage network. In addition to reducing pollutant discharges to downstream waterways, these measures can have major aesthetic benefits to an area typically in desperate need for cosmetic enhancements. Overall, the implementation of an intensive housekeeping program can improve the quality of urban receiving waters and reduce the potential for localized flooding under minimal storm events due to a reduction of the storm sewer system's hydraulic capacity. It should be clear, though, that the quantifying the overall effectiveness of a housekeeping program is difficult because of variations of the build-up of pollutants and the characteristics of storm events.

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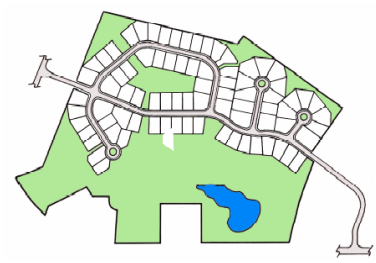
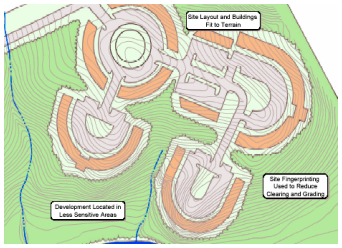
ACTIVITY: Urban Stormwater Pollution Prevention Plans

NS – 05





Description

Local Versus State Requirements

A stormwater pollution prevention plan (SWPPP) is usually prepared only if required by Tennessee Department of Environment and Conservation (TDEC). However, the local engineering department may require a SWPPP at the discretion of the stormwater manager on the basis of: 1) sound engineering judgment, 2) type of business, or 3) a history of water pollution at this site or by this owner/operator at other sites. Typical properties or land uses that require a SWPPP include:

- Vehicle fueling stations
- Vehicle service and maintenance facilities
- Vehicle and equipment cleaning facilities
- Fleet storage areas (for cars, buses or trucks)
- Industrial and commercial sites
- Outdoor loading/storage/transfer facilities
- Salvage and recycling facilities (including junkyards)
- Marinas and boat maintenance facilities
- Commercial nurseries
- Construction sites

Selection Criteria

TDEC has specific requirements for any SWPPP that is part of the NPDES permit program. TDEC requires a contractor to submit a SWPPP for construction sites which disturb 5 acres or more, using the instructions in Tennessee Rule 1200-4-10-.05 containing general NPDES permit requirements. TDEC also requires a SWPPP for industrial or commercial facilities with the potential to pollute waters of the state, using the instructions in Tennessee Rule 1200-4-10-.04 containing general NPDES Permit requirements. These two rules may be viewed and printed from the TDEC website (http://www.state.tn.us/environment/permits/). In addition, the TDEC website also has a summary of environmental permits that are required to meet state and federal regulations.

While TDEC does not require a SWPPP for Phase II Post-construction stormwater management, it is recommended that a plan be considered. Development projects can be planned and designed to reduce both water quantity and water quality impacts on watershed when careful efforts are made to conserve natural areas, reduce impervious cover and better integrate stormwater treatment. By implementing a combination of these nonstructural approaches, it is possible to reduce the amount of runoff and pollutants that are generated from a site and provide for some nonstructural on-site treatment and control of runoff.

Reduction of adverse stormwater runoff impacts through the use of better site design should be the first consideration of the design engineer. Operationally, economically, and aesthetically, the use of better site design practices offers significant benefits over treating and controlling runoff downstream or retrofitting an expensive fix after the project is developed.

The reduction in runoff and pollutants using better site design can reduce the required runoff peak and volumes that need to be conveyed and controlled on a site and, therefore, the size and cost of necessary drainage infrastructure and structural stormwater controls. In some cases, the use of better site design concepts can be viewed as both a water quantity and water quality management tool.

The goals of better site design include:

- Managing stormwater (quantity and quality) as close to the point of origin as possible and minimizing collection and conveyance
- Preventing stormwater impacts rather than mitigating them
- Utilizing simple, nonstructural methods for stormwater management that are lower cost and lower maintenance than structural controls
- Creating a multifunctional landscape
- Using hydrology as a framework for site design

The remainder of this chapter is devoted to preparing a Stormwater Pollution Prevention Plan (SWPPP) for the city that is not specifically required by TDEC. SWPPP requirements are generally similar to those described in the cited Tennessee rules and in other EPA and state documents (see EPA, 1992; Georgia, 2001)

The life history of a SWPPP generally includes three broad phases:

1. Site Evaluation
2. Planning and Design
3. Implementation and Monitoring

Preparing a SWPPP involves the first two phases of the life history but requires careful consideration of how the third phase will be handled. The SWPPP shall include a methodology for adding letters, memos, inspection reports, monitoring data, maintenance records, leak/spill information, etc. The SWPPP is intended to be a living document that will serve the site owner/operator in meeting many environmental needs.

Phase 1: Site Evaluation

This requirement is intended to be a one-time event if a SWPPP is maintained properly. If the SWPPP is not maintained properly, then a complete site evaluation may be required again whenever new construction or redevelopment takes place.

Step 1: Select a pollution prevention team. A specific individual will be in charge of

developing and maintaining the SWPPP. As a minimum, there must be one other team member who is familiar with the specifics of the SWPPP and who can take charge in the absence of the leader. Pollution team members must be aware of all activities at the site. For large project sites, there may be many pollution team members.

Step 2: Conduct a site assessment, including a review of all available information and records. A site map must be developed that includes all known structures, drainage features, material storage, known leaks and spills, historical information such as date of construction, etc. Additional items to be shown include soil types, vegetation, contours, drainage outfalls, size and material of stormwater pipes and manholes, floor drains, parking areas, and method of roof drainage. The site map must be drawn to scale, legible, properly labeled, and reproducible.

Step 3: Develop a comprehensive materials inventory to include material safety data sheets (MSDS). All materials and liquids should be included on the list, no matter how small the quantity involved. The list should include the name of material, location stored, type of container, volume of material, use of material, safeguards in place to prevent pollution, and whether a MSDS is required. The list should also indicate which materials are exposed to stormwater and the quantities involved.

Step 4: Identify all non-stormwater discharges, including past spills and leaks. A non-stormwater discharge is any material that is released intentionally or unintentionally to the ground surface, to a storm sewer system, or to a natural channel. Provide a list of significant spills and leaks that have occurred within the last 3 years, using the federal definition of a reportable quantity. A reportable quantity of each material can be defined using the federal regulations contained in 40 CFR 302.4, 40 CFR 117.21, and 40 CFR 110.10.

Step 5: Provide monitoring data to identify non-stormwater discharges, past spills and leaks, and the current level of pollution from the various site outfalls. Stormwater sampling must be conducted for several parameters that are deemed to be important by the local municipality. The parameters are subject to change: 1) from watershed to watershed, 2) over a period of time, and, 3) as directed by agencies having control over the citywide NPDES permit. Therefore, it is essential to contact the local engineering department for further guidance on stormwater sampling parameters.

Step 6: Evaluate the gathered data and to write a site evaluation summary. The use of electronic drawings and spreadsheets is encouraged and will generally allow the SWPPP preparer to make changes as necessary. The narrative should concentrate on activities with a high potential for contaminating stormwater.

Phase 2: Planning and Design

What changes can be made to improve stormwater quality? What can be done to reduce the possibility of a spill or release? How can monitoring and sampling be made easier and more consistent?

Step 1: Identify BMPs and good housekeeping practices necessary to improve operations. The most effective BMP is to hire good employees and to provide them with consistent training. An employee training manual, as part of a well-designed training program, can be a simple and cost-effective method to ensure good

housekeeping practices.

Step 2: Identify ways to improve work methods and ways to reduce stormwater pollution. The second-most effective BMP is to use the proper equipment and materials. For instance, a commercial or industrial site should consider equipment upgrades and improvements as necessary. A construction site should identify erosion and sediment control measures. Most sites should consider the use of stormwater control measures (grass buffer zones, detention basins, and oil-water separators) to reduce stormwater pollution leaving the site.

Step 3: Design a program for operations and maintenance, including regularly scheduled inspections and testing. Record keeping is essential to this program; an electronic database is almost a necessity for many types of sites. Ensure that inspection records have a standard format with complete information, in case of an audit. Inspection records must be kept for at least three years.

Step 4: Design a spill prevention and response program. Safety measures and emergency contact telephone numbers must be identified and then posted on the site for quick use. Include procedures for notifying regulatory authorities (city engineering department, TDEC) and emergency responders (police, fire, hospital). Describe spill containment, isolation, and cleanup measures that would be used. Although the local fire department can assist with spill or leak containment, the responsible party will be expected to remediate any pollution. It is highly recommended that a spill response program shall include contacting a few remediation contractors or emergency response contractors.

Phase 3: Implementation and Monitoring

This phase essentially involves the actual performance of everything identified within Phase 2. It may be necessary to develop an implementation schedule and cost estimate if some items are being phased in.

Step 1: Train employees properly in accordance with a good employee training program that is carefully documented, typically with tests or quizzes. State and federal agencies, depending on materials involved or the type of business may mandate additional training requirements.

Step 2: Use the BMPs identified previously in the SWPPP. Proper construction or installation of all items is necessary for them to function properly. Document each item as it is being installed; pictures are generally preferable to supplement sketches. Correctly store all operating procedures, repair manuals, spare parts, and receipts for immediate use and/or reference.

Step 3: Purchase a spill containment kit or materials. Train all personnel about where materials are stored, when to use spill containment, emergency notification procedures, and the disposal of used spill containment materials.

Step 4: Inspect and maintain the site as described in the design phase. Inspection duties must be assigned to a responsible person in order to ensure proper inspection schedules and record keeping.

SWPPP Preparation Guidance

The following checklist is a short version containing some of the typical elements for SWPPP preparation. Additional information may be necessary due to the nature of the site. The EPA documents for preparing pollution prevention plans (references 137 and 138) contain additional checklists and examples. Tennessee Rule 1200-4-10-.04 may be used as guidance in preparing a SWPPP for industrial sites. Tennessee Rule 1200-4-10-.05 may be used as guidance in preparing a SWPPP for construction sites.

1. Complete site description, address, and purpose
2. Pollution prevention team with complete contact information
3. Signature page for responsible persons
4. Pertinent project correspondence and project history
5. Description of potential pollutant sources
6. Existing topography, grading, vegetation
7. Information on soils and groundwater
8. Site drainage map, including outfall locations and sinkholes
9. Existing and proposed drainage structures (size, material, dimensions, etc.)
10. Material storage areas
11. Inventory of exposed materials within the last 3 years
12. List of known spills and leaks within the last 3 years
13. List of non-stormwater discharges within the last 3 years
14. Sampling data within the last 3 years
15. Good housekeeping measures and BMPs
16. Inspection and maintenance schedule
17. Inspection and maintenance records
18. Spill prevention and response procedures
19. Material safety data sheets
20. Inventory and location of spill prevention materials
21. Employee training
22. Record keeping and reporting procedures
23. Copy of NPDES permit and/or application

References

City of Knoxville Engineering Department Planning Division. “Knoxville BMP Manual”, March 2001.

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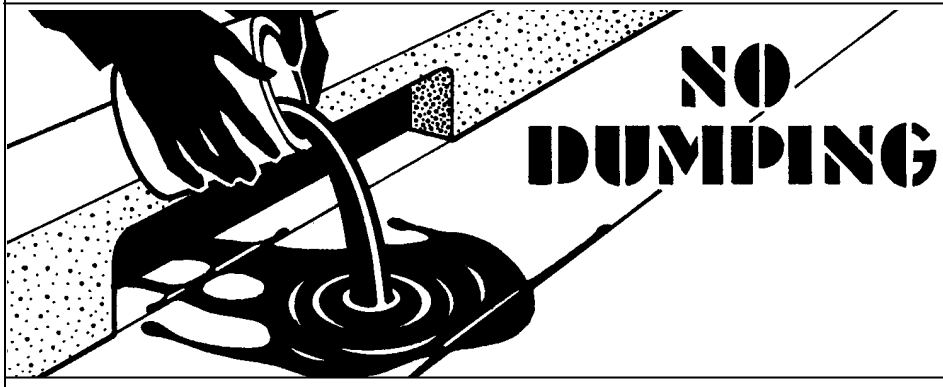
ACTIVITY: Non-Stormwater Discharges to Storm Drains

NS – 06



Description

The purpose of this activity is to help eliminate non-stormwater discharges to the stormwater collection system. Non-stormwater discharges may include oils, paints, acids, solvents, process wastewaters, cooling waters, wash waters, and sanitary wastewater. This task will help eliminate all types of pollution such as nutrients, heavy metals, toxic materials, floatable debris, oil and grease, bacteria and viruses, and oxygen demanding substances.

Approach

Non-stormwater discharges to the stormwater collection system may include any water used directly in the manufacturing process (process wastewater), non-contact cooling water, outdoor secondary containment water, vehicle and equipment wash water, sink and drinking fountain wastewater, sanitary wastes (including "gray water" discharged from washing machines or dishwashers), or other wastewaters.

In addition to mechanical discharges, employees or subcontractors could dump or pour materials directly into a storm drain or open channel. Common substances illegally dumped on the street or directly into the storm drain system and creeks include: paint, used oil, automotive fluids, construction debris, chemicals, fresh concrete, leaves or grass, mop water, and pet wastes. All of these wastes can cause quality problems for stormwater and receiving waters as well as clog the storm drain system itself. The reader is referred to other reference sources for disposal alternatives for various types of discharges and waste-producing activities. For example, the City of Knoxville's Stormwater BMP Manual provides a very helpful table in its employee training section, "Quick Reference for Disposal Alternatives" (Knoxville, 2001).

Many businesses, commercial facilities and industries are required to obtain a National Pollutant Discharge Elimination System (NPDES) permit as part of their operations. Requirements to identify and eliminate non-stormwater discharges are integral to every NPDES permit. Keys to this activity are information and investigation.

This BMP should be very closely coordinated with employee training, in that the principal goal is to eliminate all substances (liquid or solid) that do not belong in stormwater. Employee training and knowledge is the beginning point for solving stormwater pollution problems. Employee training is considered by many stormwater managers to be the most critical aspect of controlling stormwater pollution. An employee who is trained at the start will recognize and understand activities that pollute stormwater. An untrained employee may not perform the task correctly and may never learn to do it the right way after the initial opportunity is lost. Management should integrate key elements from individual BMPs into a comprehensive training program.

Some stormwater ordinances specifically describe what is allowable to discharge into the stormwater; all other discharges are prohibited by ordinance. The following non-stormwater discharges are typically considered allowable:

1. Water line flushing
2. Landscape irrigation
3. Diversion of stream flows or rising groundwater
4. Infiltration of uncontaminated groundwater
5. Pumping of uncontaminated groundwater from potable water sources, foundation drains, irrigation waters, springs; or water from crawl spaces or footing drains
6. Lawn watering
7. Individual car washing on residential property; or car washing of less than two consecutive days in duration for a charity, nonprofit fund raising or similar noncommercial purpose
8. Dechlorinated swimming pool discharges
9. Street washing by municipal vehicles or by municipal subcontractors
10. Any activity authorized by a valid NPDES permit
11. Any flows that result from firefighting
12. Air conditioning condensate or refrigeration condensate
13. Flows from riparian habitats and natural wetlands

The director of engineering for the municipality has the authority to order the above listed activities to be stopped or modified if sewage, industrial wastes, or other objectionable wastes are being discharged to the stormwater system. Non-stormwater discharges, even if there are no pollutants present, may have different temperatures than the ambient stream temperature. Manmade temperature variations, whether continuous or intermittent, in a natural stream may cause loss of habitat to aquatic organisms and to vegetation.

General Guidelines

To ensure that the stormwater system discharge contains only stormwater, commercial and industrial facilities should:

- Locate all discharge points from the property. Identify where discharges lead into the municipal storm sewer system or into "Waters of the State" (as defined by the blue-line streams and lakes from the USGS quadrangle map). At a minimum, use construction drawings, as-built drawings, pipeline schematics, visual observation by walking the property boundary and by examining all indoor pipes.

- Use additional methods as appropriate for locating discharge points.
  - Dye tracing
  - Inserting TV camera
  - Chemical field test kits
  - Smoke tests
  - Surface water sampling
  - Groundwater sampling

- Isolate discharges one at a time to verify source

- Develop a plan to eliminate illicit connections.
  - Plug illicit discharge points.
  - Repair or replace discharge lines as necessary. Examine types of disposal options. Use alternative products or methods to reduce the amount of pollution.
  - Repair sewer lines or connect to sanitary sewer system. Coordinate with local utility for permission to connect to sanitary system.

- Document that non-stormwater discharges have been eliminated by recording tests performed, methods used, dates of testing, and onsite drainage points observed.

Investigation

The following lists include further information on investigation activities.

- A piping schematic or sketch will show pipes and stormwater systems used to carry wastewater, cooling water, sanitary wastes, etc. Look carefully at the drawing to determine date, accuracy, and level of information. Sometimes it may be necessary to interview the field engineer or a construction worker to determine what was built.

- Visual observation of the property boundary should be conducted during daylight hours in both dry weather and wet weather. Ideally, visual observation should also include different times of the year that may affect the groundwater level and the amount of heavy vegetation.

- Visual observation of indoor pipes includes inspecting the path of floor drains in older buildings, where it is not uncommon to find cross-connections. Examine materials, condition and repairs for each pipe as a clue to what it may carry.

- A dye test can be performed by simply releasing a non-harmful tracing dye into a sanitary or process wastewater system and examining potential discharge points into the stormwater collection system for discoloration.

- TV and visual inspections can identify illicit connections to the storm sewer, but further testing is usually required (dye, smoke, isolation) to identify sources.

- Smoke testing of wastewater and stormwater collection systems is commonly used to detect connections between the two systems. During dry weather a stormwater collection system is filled with smoke and then traced to sources. The appearance of smoke in a waste vent pipe, sewer manhole, or even the base of a toilet indicates that there may be a connection between the sanitary and stormwater systems.

Limitations

- Many facilities do not have accurate, up-to-date schematic drawings. Mistakes in construction may not be reflected in the schematics. It can be difficult to locate illicit connections especially if there is groundwater infiltration.

- The easiest method is to inspect each discharge point during dry weather. Keep in

mind that flow from a storm event can continue for three days or more, and that groundwater often infiltrates the underground stormwater collection system.

References

California State Water Resources Control Board (SWRCB), *General Industrial Storm Water Permit*, 1992.

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Camp Dresser & McKee, Woodward-Clyde, Aguilar Engineering, Psomas & Associates, MK Centennial, *Planning and Design Staff Guide Update, Caltrans Storm Water Quality Handbooks*, prepared for the California Department of Transportation, 1997.

City of Knoxville Engineering Department, Planning Division. "Employee Training (Section AM-01), Table AM-01-1." *City of Knoxville BMP Manual.* 1991.

San Francisco Bay Regional Water Quality Control Board (SFBRWQCB), *General NPDES Permit for Discharges of Storm Water Associated with Industrial Activity in Santa Clara County to South San Francisco Bay or its Tributaries*, 1992.

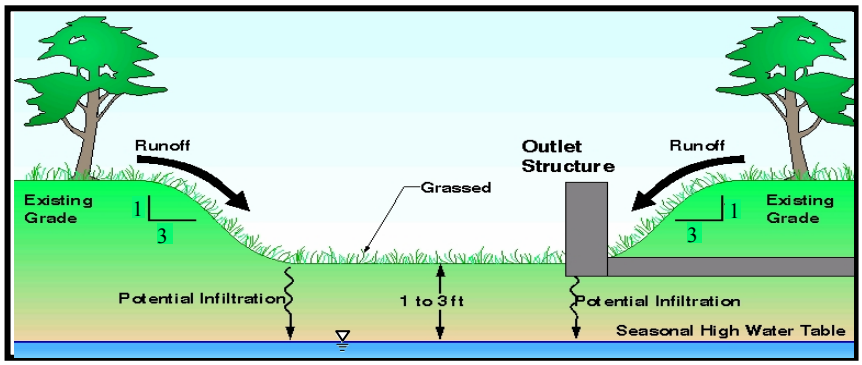
United States Environmental Protection Agency (USEPA), *Storm Water Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices*, EPA 832-R-92-006, September 1992.

Structural Best Management Practices (BMPs)

Basins (Ponds)

ACTIVITY: Detention (Dry) Basin

P – 01



Targeted Constituents				
● Significant Benefit		◗ Partial Benefit		○ Low or Unknown Benefit
● Sediment	◗ Heavy Metals	◗ Floatable Materials	◗ Oxygen Demanding Substances	
◗ Nutrients	◗ Toxic Materials	◗ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes

Implementation Requirements		
● High	◗ Medium	○ Low

◗ Capital Costs	◗ O & M Costs	◗ Maintenance	○ Training

Description

A detention basin (also known as a detention pond) is the most common method to satisfy both stormwater detention and stormwater quality requirements. It is applicable to small and large developments, can be easily designed and constructed, and is long-lasting and durable while reducing peak flows (with adequate inspection and maintenance). This practice will also provide a significant reduction in sediment, as well as a partial reduction in nutrients, toxic materials, heavy metals, floatable materials, oxygen demanding substances, and oil and grease.

A dry detention basin is intended to drain dry between storm events, but sometimes may not have a chance to drain completely between closely occurring storm events. The detention basin begins to fill as stormwater runoff enters the facility. The first flush volume is captured in order to ensure water quality. One or more outlet structures then release the stormwater runoff slowly to reduce peak discharge rates and to provide time for sediments to settle. Litter and debris should be prevented from leaving the detention basin (thus protecting Tennessee's streams and lakes). Some soluble pollutants are captured by a combination of vegetation and soils.

Selection Criteria

- The primary objective is to reduce the incoming peak flow discharge and slow the stormwater runoff response from a particular property or development, thus reducing flooding downstream. In Tennessee, peak flow runoff after development should not be greater than it was prior to development.
- The secondary objective is to remove suspended sediments, trash and debris, oil, grease and other pollutants to protect the water quality of Tennessee streams and channels. Although dry detention basins are usually not as effective at removing soluble pollutants as wet detention basins and wetlands, dry detention basins are usually easier and less expensive to construct, inspect and maintain. Dry detention basins can be used wherever a lack of sufficient supply water would prevent the use of wet detention basins or wetlands.
- Dry detention basins can also supply multiple benefits for passive recreation during dry periods (recreational trails, ball fields, picnicking). Portions of a dry

detention basin that are not wetted frequently can be attractively landscaped or used for other purposes. See NS-02, Landscaping and Vegetative Control Practices, for the use of buffer zones and typical placement of various stormwater treatment BMPs.

- Dry detention basins may be appropriate to areas where dry weather base flow cannot be used to maintain water levels, as is required for wet ponds and constructed wetlands.

Design and Sizing Considerations

- A permanent detention basin design must be stamped by a professional engineer licensed in the state of Tennessee. The professional engineer must be qualified by education and experience to perform the necessary hydrologic and hydraulic calculations. A wet detention basin must be located and designed so that failure of the structure will not result in danger to human life, damage to personal property, inundation of public streets or highways, interruption of public services or utilities, or inconvenience to the general public.

- As the primary objective, dry detention basins must be designed to have adequate detention storage and outlet structures. Multi-stage detention is required for the 1-year, 2-year, 5-year and 10-year design storm events in all watersheds. Additional stages (i.e. 25-year, 50-year, and 100-year) may be required for special watersheds.

- As the secondary objective, water quality is obtained through the use of the first flush treatment volume. The initial wave of stormwater runoff is more likely to contain aerially-deposited sediments, particulates from vehicles (such as incomplete combustion, dust from brake linings, tire particles), leaves, trash, cigarette butts, etc. The first flush volume must be captured and then slowly released. The overall goal for stormwater treatment is based on 75% removal of total suspended sediments for first flush volume.

- Additional measures may be required to improve stormwater quality, depending upon the nature of the land use and expected pollutants. Pretreatment of stormwater runoff with a media filtration inlet or oil/water separator may be necessary. A trash rack for capturing floating debris is generally considered to be standard equipment for a stormwater treatment BMP.

- Stormwater runoff that falls onto pavement and rooftops should be detained and treated in a manner that will reduce thermal impacts to streams. This may include locating a detention basin away from sunlight by using trees or buildings as shade.

Location and Layout

Basic elements of a dry detention basin are illustrated in Figure P-01-1. The recommended design includes the use of a sediment forebay to reduce sediment loading, particularly if the post-construction detention basin is a modification from a temporary sediment basin during the construction phase. The use of an upper stage (for storage of infrequent storms) is optional; there are both benefits and drawbacks. A shallow detention basin with a large surface area will usually perform better than a deeper detention basin with the same volume. However, shallow storage areas increase the overall surface area needed for detention.

Design flow paths to minimize potential short-circuiting by locating the inlets as far away from the outlet structure as possible. The length-to-width ratio of a basin should be at least 2:1 (and preferably 3:1). Baffles or backslope drains may be used to prevent short-circuiting. If topography or aesthetics require the pond to have an irregular shape, increase pond area and volume to compensate for dead spaces. It is important to reduce the velocity of incoming stormwater using riprap or other energy dissipaters.

Although dry detention basins are generally less expensive to construct and maintain than wet detention basins, they provide lower water quality benefits. The primary disadvantage of a dry detention basin is the amount of surface area required, which can be reduced somewhat by using concrete retaining walls on one or more sides. In general, concrete retaining walls should not face southward in order to reduce the potential for heating on hot summer days.

Bedrock and topography must be considered when grading in some areas of the state. Karst topography may indicate fractured bedrock, dissolved limestone passages, or sinkholes, for which a detention basin would be highly detrimental. The additional water volume that is introduced to the underground limestone passages, or even the additional weight of ponded water, could intensify karst activity and eventually collapse the bed of the detention pond.

Interaction with site utilities must be considered during preliminary design. Typical utilities include electrical, telephone, cable TV, water, sewer, natural gas, petroleum, etc. These utilities may or may not be in a dedicated utility easement, so it is always necessary to conduct a careful site survey. Detention basins (including embankments) should not be allowed over utility lines. Conversely, utility trenches should not be constructed on existing detention basin structures.

Detention basin easements and access must be considered during preliminary design, in order to allow for the construction easement and maintenance. Detention basins that are not frequently inspected and maintained often become more of a nuisance than a beneficial part of a stormwater management program. In particular, provide access for inspection and maintenance to the sediment forebay and to the outlet control structure. It may also be desirable to encourage or discourage public access to the detention basin (by using site grading, signs, fences or gates). Additional safety elements include trash racks, grating over pipes and culverts, gentle side slopes whenever possible, increased visibility and/or lighting in residential areas, etc.

Small detention basins serving individual properties do not offer as much recreational benefits as community or regional detention basins would. Regional facilities can often be landscaped to offer recreational and aesthetic benefits. Jogging and walking trails, picnic areas, and ball fields are some of the typical uses. For example, portions of the facility for flood control of major design storms can be used for exercise areas, soccer fields, or football fields. Wildlife benefits can also be provided in the form of islands, buffer areas, or preservation zones. It is important to maintain such areas, however as their primary purpose is for stormwater management. Under no circumstances should debris be allowed to accumulate near the outlet.

Volume and Size

The volume of a dry detention basin consists of two elements: the live pool (the upper portion of the basin representing detention capability) and the first flush volume (the

lower portion of the basin representing stormwater quality treatment).

Since the post-development peak runoff may not exceed the pre-development peak flow rate, the upper section's volume should be greater than or equal to this difference in volume.

The first flush volume should be sized to capture and slowly release the "first flush" of stormwater runoff, or the volume most likely to contain contaminants and particulate matter. Common practices include slow release of the first one-inch of runoff over a 24 to 72 hour period, or the detention of a 1-year storm.

As a warning to those who design detention basins, it should be realized that future stormwater regulations are likely to be more stringent than the current regulations. This is mostly driven by national and state laws and regulations, which will require municipalities and county governments to accomplish additional pollution reduction with a proportional effort for water quality monitoring and enforcement. Figure P-01-6 shows the measured pollution removal values during the 1980's for dry detention basins near metropolitan Washington, D.C.

Grading

Side slopes of detention basins and embankment dams shall generally be 3H:1V or flatter. This encourages a strong growth of vegetation on the side slopes, helps to prevent soil erosion, and allows for safer mowing. Steep slopes, particularly on embankments or other fill soils, will contribute to soil erosion if not properly vegetated or stabilized, and thereby reduce or negate the effectiveness of a dry detention basin with respect to water quality. Vegetate the side slopes and basin bottom to the maximum extent practical. If significant side erosion is expected, consider the use of soil stabilization or armoring techniques. Detention basins should not be located immediately above or below a steep slope or grade, because impounded water may create slope stability problems.

Minimum width for top of embankment is 5 feet. The embankment height should allow for up to 10% settlement of embankment, unless the embankment is thoroughly compacted with vibratory equipment or sheepsfoot rollers. The top of embankment (after expected settlement) shall generally be at least 2 feet above the top of outlet structure and at least 1 foot above the peak 100-year water surface elevation. Compaction in the immediate area of the emergency spillway can be difficult, but is necessary.

In instances where stormwater runoff does not flow directly down a slope, the side slope of a detention basin can be as steep as 2:1 (H:V) with proper erosion controls, geotextiles, and quick establishment of vegetation. Retaining walls may be used on one or more sides of a detention basin if properly designed. Analysis of a retaining wall should include effects of saturated soil behind the retaining wall, in addition to the usual design considerations of vehicle and structural loadings above the retaining wall.

The use of a backslope drain can be very beneficial in preventing erosion at detention basins. See Figure P-01-5 for a typical detail. The backslope drain is also useful for increasing lengths of flow paths to prevent short circuiting of the detention basin. Intercepted stormwater can be routed around the detention basin to enter at the most hydraulically distant point from the outlet structure.

Outlet Structure

Detention basin outlet structures should be constructed of durable materials, such as concrete or masonry block. Corrugated metal pipe (CMP) and plastic (HDPE) risers and drain pipes are popular in engineering design, but are susceptible to crushing and flotation in detention basins. A concrete outlet structure is generally preferable to a masonry block structure because it is sturdier and more durable. Provisions should be made for sufficient reinforcement and anchoring.

The specific flow-controlling elements of an outlet structure may include one or more of the following: a circular orifice, a noncircular orifice, a rectangular weir, a trapezoidal weir, a triangular weir, a V-notch weir, culvert entrance control or a riser overflow opening.

Figures P-01-2 and P-01-3 illustrate possible designs for the outlet structure. These details are only two possible ways to accomplish stormwater detention and stormwater quality control. The first flush volume is typically drained during a minimum time of 24 hours by using an orifice with a designed size. Maximum drain time should be less than 72 hours to allow for sufficient volume recovery prior to the next period of rainfall. The first flush volume can be filtered through sand by using an underdrain system (shown in Figure P-01-2) or by an aboveground filter box with sand or aggregate (shown in Figure P-01-3). Figure P-01-4 shows an alternative outlet structure with a water quality manhole. Provide an emergency spillway in order to route large storms through the facility without overtopping.

Emergency Spillway

An emergency spillway should be included in addition to the primary outlet structure on a retention pond. The purpose of this spillway is to pass storm events that exceed the design capacity of the pond, in order to prevent overtopping the embankment. The emergency spillway should be located over an undisturbed abutment area and <u>not</u> over the embankment fill for stability reasons. The emergency spillway capacity should be designed to prevent overtopping the embankment structure or dam during a storm event commensurate with the impoundment volume, dam size, and downstream flood hazard potential in event of dam failure. The minimum spillway capacity should be capable of handling a 100-year storm event. The designer is referred to the requirements set forth in the Tennessee Safe Dams Act and Regulations at: www.state.tn.us/environment/permits/safedam.htm

Extended Detention Basins

The extended detention basin is similar to the detention basin, except that the water is detained for a longer period of time—usually between 24-72 hours. This BMP should be used when water quality is of greater concern, since the primary objective of this device is to hold stormwater for a given duration, instead of simply attenuating storm runoff.

Other Design Elements

- Sediment forebay – to facilitate the cleanout of sediment, trash, debris, leaves, etc. The sediment forebay typically contains 5% to 10% of the total volume. It should be located at a point where velocities have dissipated, to allow large sediments and

debris to settle out. A forebay can be separated from the remainder of a detention basin by several means: a lateral sill with rooted wetland vegetation, rock-filled gabion, rock retaining wall, or rock check dam placed laterally across the basin. The sediment forebay should be easily accessible so that it can be inspected and maintained.

- Public safety should be considered, particularly in residential areas. Operating detention basins often attract neighborhood children. Avoid steep slopes and dropoffs; consider routes for escaping the detention basin if a person accidentally falls in. Avoid depths over 4 feet when possible; provide fencing and signs in areas where children may potentially play, and where steep slopes are used in the detention area.
- A low-flow channel (or concrete trickle ditch) can assist in completely draining detention basins with flat slopes. It also assists with the observation and removal of accumulated sediment. A typical design may be a triangular ditch, maybe 4' wide and 3" deep with a slope of 0.5 to 1.0 percent.
- Depending on the embankment soil, height of dam, and amount of compaction for the embankment, an anti-seep collar or a cutoff layer of compacted clay may be needed around the outlet pipe to prevent internal piping and erosion. An anti-seep collar should extend at least one pipe diameter from the culvert in all directions, with compacted clay backfill using small mechanical tampers. In areas of abundant clay soils, an anti-seep collar is not required for a dry detention basin.
- To prevent the outlet riser from clogging, include trash racks or other debris barriers with a maximum opening size of 6 inches on all outlet structures, except for any emergency spillway structures that are designed for a 25-year storm or greater return period. Trash racks that are placed at an angle to the direction of flow tend to force debris up and away from the outlet opening and are somewhat less vulnerable to clogging. These racks should be regularly cleaned and maintained.
- Provide means for vehicle access to the detention basin. Detention basins must be located in a maintenance easement so that authorities have the right to inspect the facility. Maintenance easements that are not adjacent to a municipality's right-of-way must also have an access easement, which allows for maintenance vehicle access. This easement should be free of large trees and excessive vehicle grades.
- Include a skimmer, oil/water separator or other type of stormwater runoff pretreatment for detention basins with greater than 50 percent impervious surface or where there may be a potential source of oil and grease contamination. In addition to most large parking lots, oil and grease contamination is also likely for vehicle fueling and maintenance facilities.
- An anti-vortex device for the outlet structure may be potentially needed for very large detention basins in areas where public access is not controlled. The anti-vortex device may be a combination of vanes above the outlet structure or guide walls around the outlet structure, that increases the inlet flow efficiency and might lessen the chance of humans drowning or reduce the potential for erosion and structural undercutting.

Construction/ Inadequate storage is the most frequent problem that occurs in the design review before

Inspection Considerations

construction, and also for the as-built review after construction. This can occur for several reasons:

- The design engineer did not allow enough room to construct the detention basin (most often due to insufficient design detail such as slope transitions, setbacks, parking lot widths, inaccurate contours, utilities not shown).
- The engineer who performs the stormwater computations is not the same person as the design engineer who does site layout and grading. The required detention storage volume and outlet structure details need to be communicated clearly to the design engineer for inclusion on the plans and for construction layout.
- The construction contractor does not correctly follow the design plans, and consequently, does not excavate deep enough or build berms of sufficient height to hold the required detention volume. This may occur due to rock formations encountered or to groundwater. It is important that the elevation-volume configuration shown on the plans be preserved during construction so that the detention basin functions according to intended design.
- The construction contractor changes the basin configuration during the construction without being aware of the required volume. Approval from the engineer was not obtained for a design change.

It is highly recommended that the design engineer is involved in the construction and inspection of the detention basin. Special attention should be given to the detention basin volume, elevations of each outlet, embankment crest and emergency spillway crest; side slopes, size and shape of various weirs or orifices, and installation of cutoff collars in embankments.

Proper hydraulic design of the outlet is critical to achieving good performance for both stormwater detention and stormwater quality of the dry detention basin. The two most common problems for detention basin outlets are:

- The discharge capacity of the outlet system is too great at the detention design depth. This causes excessive basin outflows and results in fast drawdown times and inadequate filling of the detention basin volume. Both stormwater detention and stormwater quality will suffer.
- The outlet structure clogs because it is not adequately protected against trash and debris. The use of innovative trash racks is recommended. Effective trash racks are often created using welded rebar with 6-inch openings. Sloped trash racks are preferable to vertical ones for forcing floating debris upward and away from the opening, rather than being forced against the trash rack, and causing clogging. This is sufficient to stop most beverage cans, fast food containers, tree limbs, etc. Properly designed and installed trash racks also provide a measure of safety to children who may otherwise be pulled toward and held against the opening.

Maintenance

Effective and safe operation of a detention basin depends on continuous maintenance of all system components. This means that the owner should have a regular inspection program in place for checking the condition and integrity of the basin, dam, and outlet control system to prevent minor problems from becoming serious safety and operation problems. Detention basin easements and access must be considered during the

planning stage in order to allow for proper inspection and maintenance.

- As a minimum, an owner should inspect the dry detention basin regularly (several times a year) and particularly after heavy rainfall events. Record all observations and measurements taken. Perform any maintenance and repair erosion promptly. Remove debris and trash after storm events. Check outlet structures regularly for clogging.
- Remove sediment when accumulation becomes noticeable (1" to 2" over a wide area) or if resuspension is observed or probable. Sediment may be permitted to accumulate if the detention basin volume has been overdesigned with adequate controls to prevent further sediment movement. If a sand underdrain is used, look for reduced infiltration or ponded water; sand layer replacement may be needed.
- Maintain a thick and healthy stand of vegetation (usually grass). Mow or trim at regular intervals to encourage thick growth. Remove leaves, grass clippings, or sticks from detention basin regularly to prevent stormwater pollution. Remove trees or nuisance vegetation as necessary to ensure structural integrity of the basin. This is especially true in embankments. Signs should be posted at detention ponds to discourage local homeowners from depositing yard trimmings, waste, and fill materials inside the basin. Appropriate signs and barriers such as fences should also be considered at detention basins where children have easy access to the site.
- If both the operational and aesthetic characteristics of a dry detention basin are not properly maintained, recognize that it becomes an eyesore and has a negative environmental impact. Vegetation needs to be trimmed or harvested. Signs should be posted and maintained at detention ponds to warn of hazardous water conditions and to prohibit local homeowners from depositing yard trimmings, waste, and other fill materials inside the basin.

Sediment Removal

A primary function of stormwater treatment BMPs is to collect and remove sediments. The sediment accumulation rate is dependent on a number of factors including watershed size, facility sizing, construction upstream, nearby industrial or commercial activities, etc. Sediments should be identified before sediment removal and disposal is performed. Special attention or sampling should be given to sediments accumulated from industrial or manufacturing facilities, heavy commercial sites, fueling centers or automotive maintenance areas, parking areas, or other areas where pollutants are suspected. Sediment should be treated as potentially hazardous until proven otherwise.

Some sediment may contain contaminants for which TDEC requires special disposal procedures. Consult TDEC – Division of Water Pollution Control if there is any uncertainty about what the sediment contains or if it is known to contain contaminants. Clean sediment may be used as fill material, hole filling, or land spreading. It is important that this material not be placed in a way that will promote or allow resuspension in stormwater runoff. Some demolition or sanitary landfill operators will allow the sediment to be disposed at their facility for use as cover. This generally requires that the sediment be tested to ensure that it is innocuous.

Cost Generally less expensive than wet ponds and wetlands, but more expensive than

Considerations

biofilters.

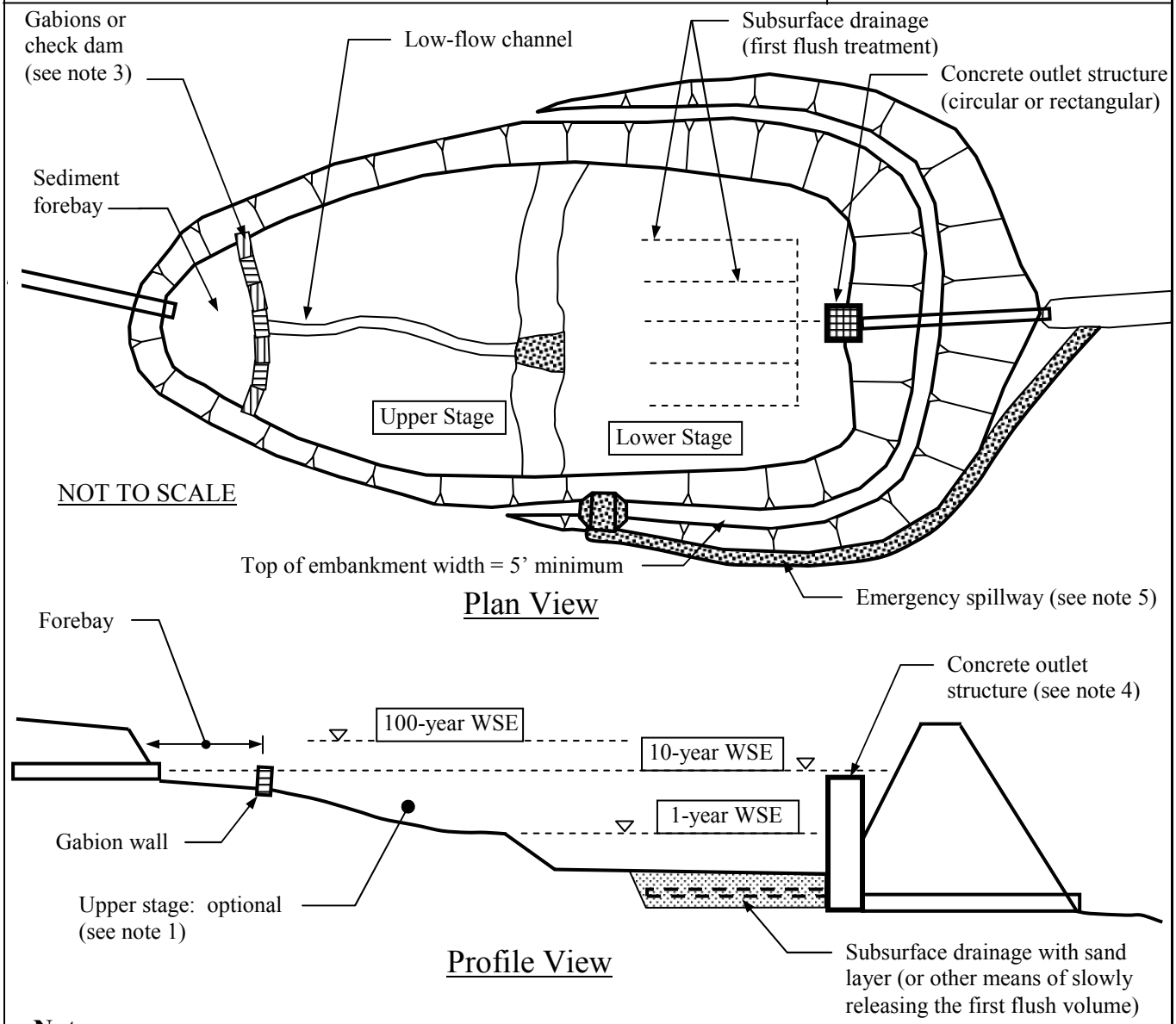
Limitations

- A dry detention basin will require frequent inspection and maintenance. Trash, debris, leaves and other large items should be removed from the detention basin following each rainfall event. If upstream erosion is not properly controlled, dry detention basins can be maintenance-intensive with respect to sediment removal, nuisance odors, insects and mosquitoes, etc. Municipalities should develop clear policies on who is responsible for maintaining detention basins.
- A dry detention basin may not have sufficient vegetation on the slopes and bottom to prevent erosion. Vegetation must be maintained and cut at adequate intervals. Remove grass clippings from detention basin immediately after cutting, using rakes or other hand equipment.
- A dry detention basin that impounds more than 30 acre-feet of volume (and minimum 6 feet high) or which is higher than 20 feet (and minimum 15 acre-feet of volume) is subject to the Tennessee Safe Dams Act of 1973 and as amended by law. The Safe Dams Act is administered by the TDEC Division of Water Supply; further information on design standards, regulations and permit applications is available at the TDEC website:

  http://www.state.tn.us/environment/permits/safedam.htm
- Dry detention basins require a relatively large surface area (typically 1% to 3% of the contributing drainage area) in order to provide sufficient pond volume for detention and water quality. Dry detention basins require a differential elevation between inlets and outlets, for which extremely flat areas may not be suitable.

Additional Information

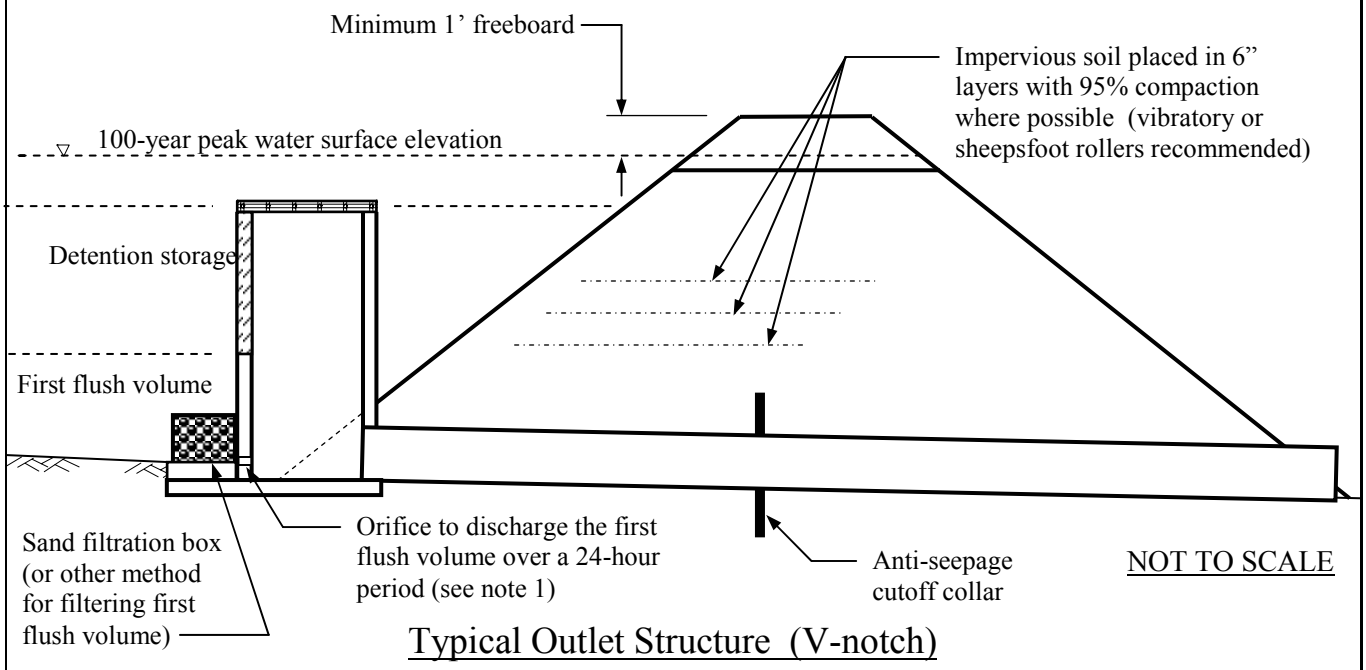
See attached figures.



Notes:

1. This example of a typical dry detention basin layout shows an upper stage which is used for stormwater detention on infrequent storms. An upper stage can also be located on the side of a dry detention basin, eliminating the need for a low-flow channel.
2. The lower stage is typically sized to handle the first flush volume or the 1-year design storm, whichever is greater.
3. A forebay can be constructed from gabions, rock check dams, or a separate berm with culvert. A forebay can facilitate the capture and cleanup of coarse sediments, debris and trash.
4. The outlet structure typically has orifices or weirs at computed elevations that will release the 1-year, 2-year, 5-year and 10-year storms at the specified predevelopment peak flow rates. Certain watersheds are also required to detain the 100-year design storm.
5. The emergency spillway is generally constructed on natural ground or excavated areas (rather than fill soils) to reduce the potential for erosion and washout.

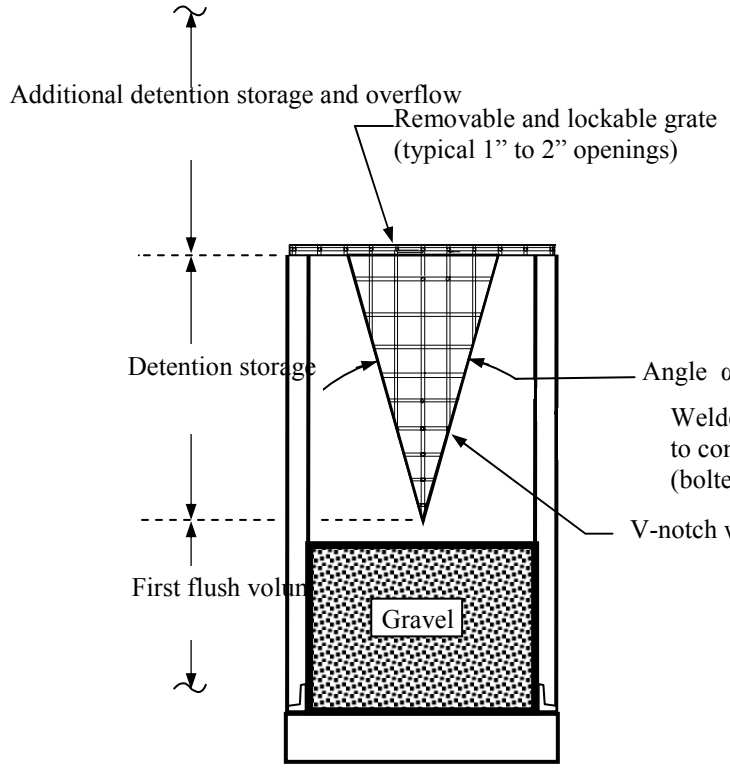
Figure P-01-1
Typical Dry Detention Basin Layout



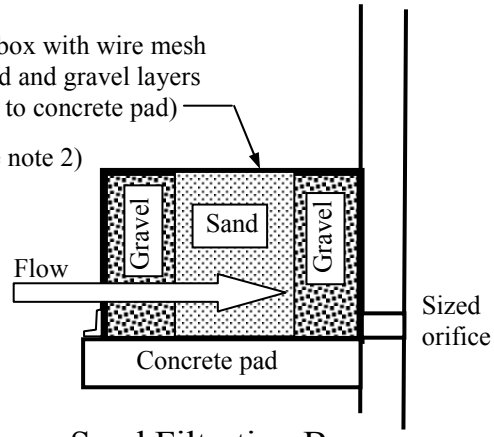
Typical Outlet Structure (V-notch)

Notes:

1. The orifice is sized to release the first flush volume over a period of 24 hours. Protect the orifice from clogging by a sand filtration box, gravel filtration box or with a trash rack.
2. This example of a typical outlet structure shows a V-notch weir which should be sized to release the 1-year, 2-year, 5-year and 10-year storm peak flows at the predevelopment rates. Other control geometries such as orifices or culverts may also be used.

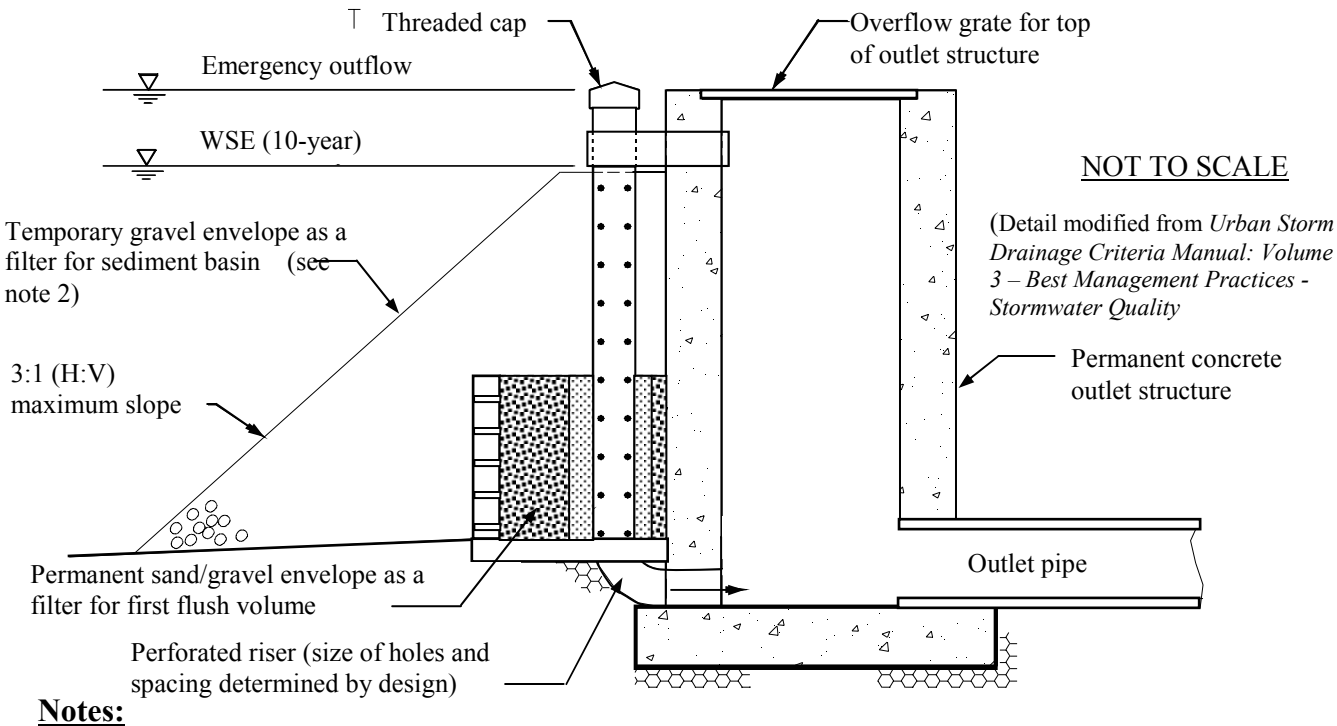


V-Notch Weir
(to control outflows)



Sand Filtration Box
(first flush release)

Figure P-01-2
Typical Outlet Structure
(shown with a V-notch weir & sand filtration box)



Notes:

1. This type of outlet structure may be used as a permanent outlet structure for a dry detention basin. Maintain clean sand/gravel envelope in unclogged condition within an enclosure in front of outlet structure to protect the perforated riser.

OR

2. This type of outlet structure may be used as a temporary modification to a dry detention basin (so that it may also be function as a sediment basin). A temporary plastic riser is securely fastened using bolts, screws or threaded connectors.

Figure P-01-3
Outlet Structure – Alternative A
(also shown as a temporary sediment basin during construction)

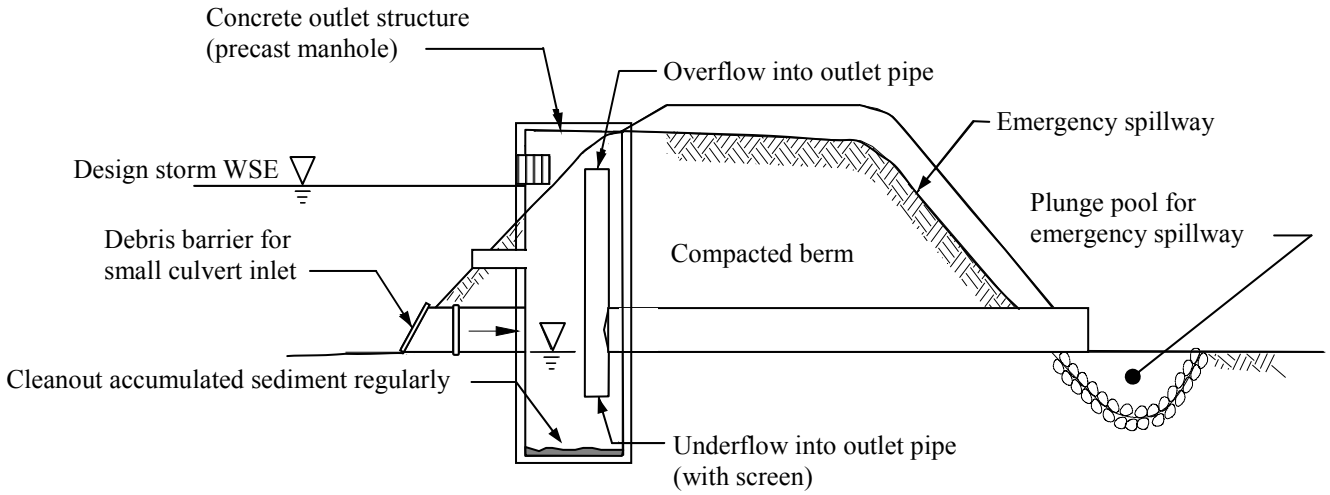


Figure P-01-4
Outlet Structure – Alternative B
(includes water quality manhole with underflow)

A backslope drain has two purposes:

1. Safely convey stormwater to the bottom of a detention basin slope.
2. Increase flow paths by channeling stormwater into the detention basin far from outlet structure.

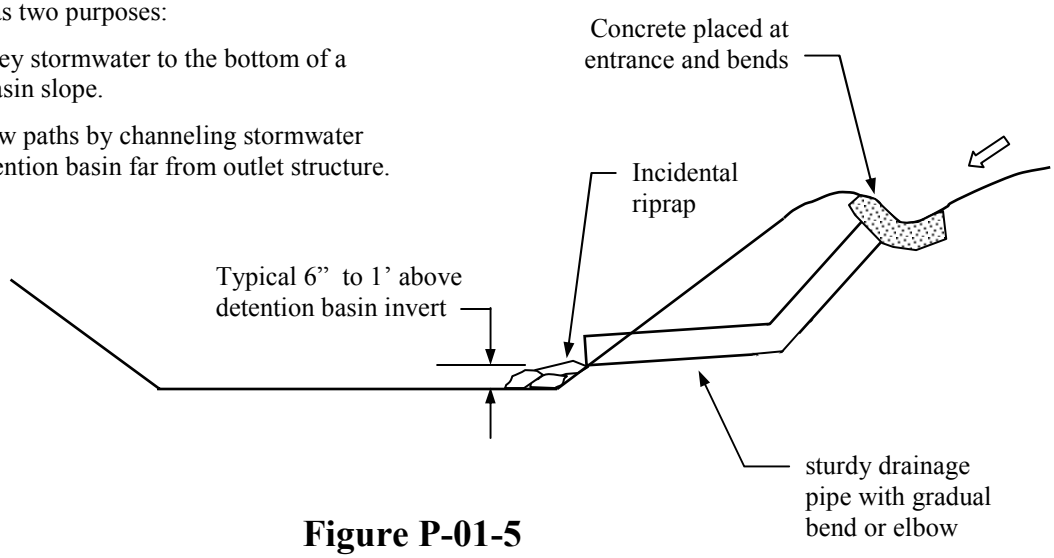


Figure P-01-5
Typical Detail - Backslope Drain

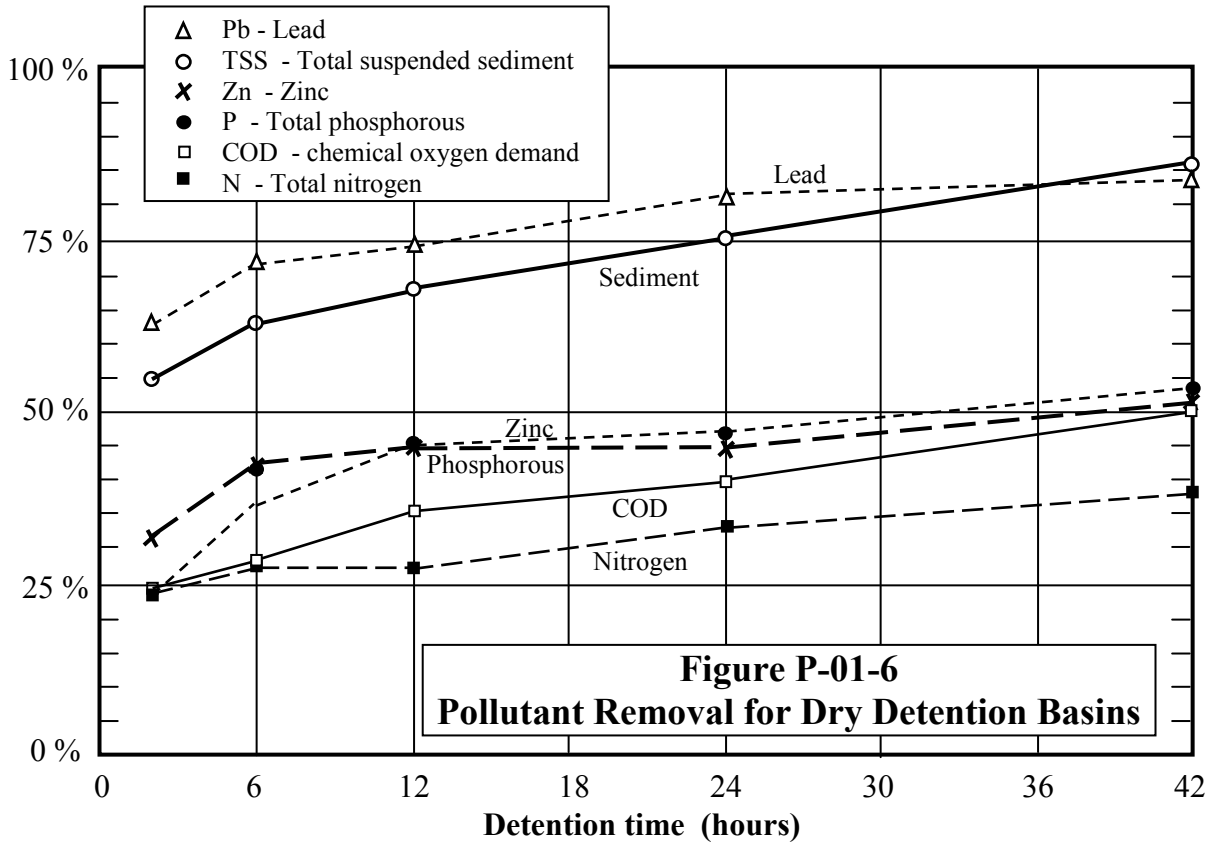


Figure P-01-6
Pollutant Removal for Dry Detention Basins

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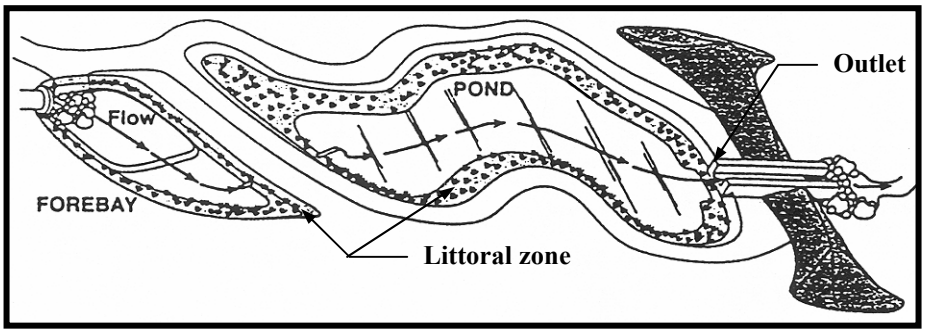
ACTIVITY: Retention (Wet) Basin

P – 02



Targeted Constituents				
● Significant Benefit		◗ Partial Benefit		○ Low or Unknown Benefit
● Sediment	● Heavy Metals	● Floatable Materials	◗ Oxygen Demanding Substances	
● Nutrients	● Toxic Materials	◗ Oil & Grease	◗ Bacteria & Viruses	○ Construction Wastes

Implementation Requirements			
● High		◗ Medium	○ Low
● Capital Costs	◗ O & M Costs	◗ Maintenance	○ Training

Description

A wet detention basin (also known as a retention pond) is a very desirable method to satisfy both stormwater detention and stormwater quality requirements. It is applicable to most locations for which the contributing drainage area runoff can support a permanent pool of water. Karstic areas prone to sinkhole conditions deserve special attention. A wet detention basin can be enhanced with other stormwater treatment BMPs such as a pretreatment sediment forebay, baffle box, or stormwater quality inlet.

This practice will provide a significant reduction in sediment and most types of pollutants. A wet detention basin, with its permanent pool, is generally more effective than a dry detention basin at allowing sediments and other pollutants to more effectively settle out.

Selection Criteria

- A primary objective is to reduce the incoming peak flow discharge and slow the stormwater runoff response for a particular property or development, thus reducing flooding downstream.
- Another important objective is to enhance the removal of suspended sediments, trash and debris, oil, grease and other pollutants to protect the water quality of Tennessee streams and channels. Wet detention basins not only enhance physical settling of sediments and pollutants, but will also permit a limited amount of chemical mixing and interaction of dissolved nutrients and metals. Biological uptake will also occur to some degree within a wet detention basin. Dissolved contaminants are removed by a combination of physical adsorption to bottom sediments and suspended fine sediments, natural chemical flocculation, and uptake by aquatic plants.
- Wet detention basins are ideal for large regional detention facilities; larger drainage areas are likely to have a minimum base flow entering the system. Wet detention basins should be used if it is imperative to achieve high levels of particulate and dissolved contaminant removal.

- Wet detention basins also can provide riparian benefits for passive recreation during dry periods (recreational trails, picnicking, bird watching, and wildlife habitat). Portions of a wet detention basin that are not wetted frequently can be attractively landscaped or used for other purposes.

Design and Sizing Considerations

A permanent detention basin design must be stamped by a professional engineer licensed in the state of Tennessee. The professional engineer must be qualified by education and experience to perform the necessary hydrologic and hydraulic calculations. A wet detention basin must be located and designed so that failure of the structure will not result in danger to human life, damage to personal property, inundation of public streets or highways, interruption of public services or utilities, or inconvenience to the general public.

- As the primary objective, wet detention basins must be designed to have adequate detention storage and outlet structures. Multi-stage detention is required for the 1-year, 2-year, 5-year and 10-year design storm events in all watersheds. Additional stages (i.e. 25-year, 50-year, and 100-year) may be required for special watersheds.

- The secondary objective, water quality, is obtained through capture of the first flush volume, and also the retention and mixing of stormwater runoff with the permanent pool storage volume. This volume is more likely to contain sediments, particulates from vehicles (such as incomplete combustion, dust from brake linings, tire particles), leaves, trash, cigarette butts, etc. The first flush volume must be captured and then slowly released over a minimum 24-hour period (and a maximum time period of 72 hours). The permanent pool storage volume should be designed with vegetation around the water surface, with riprap or non-erosive materials near inlet and outlet structures. Sediments and particulates continue to settle in the permanent pool storage volume for a few days after a rainfall event.

- Additional measures may be required to improve stormwater quality, depending upon the nature of the land use and expected pollutants. Pretreatment of stormwater runoff with a media filtration inlet or oil/water separator may be necessary. A trash rack for capturing floating debris is generally considered to be standard equipment for a stormwater treatment BMP. Stormwater runoff that falls onto pavement and rooftops should be detained and treated in a manner that will reduce thermal impacts to streams, such as locating a detention basin away from sunlight by using trees or buildings as shade.

The major features of a retention basin are shown in Figure P-02-1. It is essentially a small pond or lake with rooted wetland vegetation along the perimeter. The storage volume can be divided into two portions: 1) live detention storage , and 2) permanent pool storage.

The live detention storage (above the lowest opening in the outlet structure) provides peak flood control, erosion control and additional treatment benefits. The recommended design includes a sediment forebay (or even multiple fore bays) wherever the stormwater runoff enters the wet detention basin. Live detention storage can also include areas which are not frequently inundated; these areas may have multiple recreational uses. The storage volumes necessary to limit peak flow discharges from a wet detention basin to predevelopment peak flows need to be computed. Live detention storage volume is computed using the same methods for both detention basins and retention basins.

The permanent pool storage volume (below the lowest opening in the outlet structure) provides a quiescent volume for settling of particulate contaminants and the uptake of dissolved contaminants by aquatic plants between storms. Wetland vegetation (in the littoral zone) will improve removal of dissolved contaminants, reduce the formation of algae, stabilize the shoreline and reduce waves, provide dissolved oxygen and habitats for aquatic organisms, and create attractive landscaping. The permanent pool storage volume is computed to determine a minimum residence hydraulic time, which is the average time that a drop of water is expected to remain in the wet detention basin.

Location and Layout

Basic elements of a retention basin are illustrated in Figures P-02-1 and P-02-2. The recommended design includes the use of a sediment forebay or other stormwater treatment BMPs to reduce sediment and pollutant loading. Post-construction basins can be designed in coordination with and as a successor to temporary sediment retention structures. Principal elements in assessing the potential for a wet detention basin are the existing and proposed site conditions for soils, topography, vegetation, and the amount of available base flow.

Design flow paths to minimize potential short-circuiting by locating the inlets as far away from the outlet structure as possible. The length-to-width ratio of a basin should be at least 2:1 (and preferably 3:1). If topography or aesthetics require the basin to have an irregular shape, increase the basin area and volume to compensate for dead spaces. Reduce velocity of incoming stormwater with riprap or energy dissipaters.

Bedrock and topography must be considered when grading in some areas of the state. Karst topography may indicate fractured bedrock, dissolved limestone passages, or sinkholes, for which a detention basin would be highly detrimental. The additional water volume that is introduced to the underground limestone passages, or even the additional weight of ponded water, could intensify karst activity and eventually collapse the bed of the pond.

Interaction with site utilities must be considered during preliminary design. Typical utilities include electrical, telephone, cable TV, water, sewer, natural gas, petroleum, etc. These utilities may or may not be in a dedicated utility easement, so it is always necessary to conduct a careful site survey. Detention basins (including embankments) are not allowed over utility lines. Conversely, utility trenches should not be constructed on existing detention basin structures.

Detention basin easements and access must be considered during preliminary design, in order to allow for construction and maintenance. Detention basins that are not frequently inspected and maintained often become more of a nuisance than a beneficial part of a stormwater management program. In particular, provide access for inspection and maintenance to the sediment forebay and to the outlet control structure. It may also be desirable to encourage or discourage public access to the detention basin (by using site grading, signs, fences or gates). Additional safety elements include trash racks, grating over pipes and culverts, gentle side slopes whenever possible, increased visibility and/or lighting in residential areas, etc.

Small detention basins serving individual properties do not offer as much recreational benefits as community or regional detention basins would. Regional facilities can often be landscaped to offer recreational and aesthetic benefits. Jogging and walking trails, picnic areas, ball fields, and canoeing or boating are some of the typical uses.

For example, portions of the facility for flood control of major design storms can be used for exercise areas, soccer fields, or football fields. Wildlife benefits can also be provided in the form of islands, buffer areas, or preservation zones.

Volume and Size

The volume of a wet detention basin consists of two elements: the live detention storage (the upper portion of the basin representing detention capability) and the permanent pool storage volume (the lower portion of the basin representing stormwater quality treatment). Detention computations should generally be checked and verified by performing routing computations. The first flush volume must have a minimum size of 4000 cubic feet.

The minimum permanent pool storage volume should have a hydraulic residence time of 14 days, based on average rainfall during the wettest month of the year. In general, a longer hydraulic residence time is desirable as it allows biological and chemical assimilation of nutrients and pollutants to continue for a longer time. In addition, since sediment removal and maintenance of a wet detention basin is very difficult and costly, additional sediment storage should be designed as part of the permanent pool volume.

Since the retention basin contains a permanent pool of water, a continuous base flow may be required to achieve a constant depth of water.

Grading

The maximum slope above the permanent pool storage volume shall generally be 4H:1V or flatter for better maintenance and safety. This encourages a strong growth of vegetation on the side slopes and helps to prevent soil erosion. Steep slopes, particularly on embankments or other fill soils, contribute to soil erosion and thereby reduce or negate the effectiveness of a wet detention basin with respect to water quality. Vegetate the side slopes and basin bottom to the maximum extent practical. If side erosion is particularly severe, consider the use of soil stabilization or armoring techniques. Detention basins should not be located immediately above or below a steep slope or grade, because impounded water may create slope stability problems.

The littoral zone is an area of the detention basin which supports rooted wetland vegetation. The littoral zone should be 1 to 2 feet below the normal water level, with a gentle slope of 6:1 (H:V) or flatter. Typically the littoral zone is 10 feet wide. The remainder of the permanent pool storage volume may have slopes as steep as 2:1 (H:V); this portion of the wet detention basin is generally protected against rainfall, water velocities and wave action so that erosion does not occur.

The minimum width for top of embankment is 5 feet. The embankment height should allow for up to 10% settlement of embankment, unless the embankment is thoroughly compacted with vibratory equipment or sheepsfoot rollers. The top of embankment (after expected settlement) shall generally be at least 2 feet above the top of outlet structure and at least 1 foot above the peak 100-year water surface elevation. Compaction in the immediate area of the emergency spillway can be difficult, but is necessary.

Retaining walls may be used on one or more sides of a detention basin if properly designed. Analysis of a retaining wall should include effects of saturated soil behind

the retaining wall, in addition to the usual design considerations of vehicle and structural loadings above the retaining wall. In general, concrete retaining walls should not face southward in order to reduce the potential for heating on hot summer days. Using a backslope drain (see Figure P-01-5 for a detail) can increase the flow path lengths to prevent short circuiting of the detention basin.

Outlet Structure

Detention basin outlet structures should be constructed from durable materials such as concrete or masonry block. Corrugated metal pipe (CMP) and HDPE (plastic) risers and drain pipes are popular in engineering design, but are susceptible to crushing and flotation for detention basins. A concrete outlet structure is generally preferable to a masonry block structure because it is sturdier and more durable. Provisions should be made for sufficient reinforcement and anchoring.

The specific flow-controlling elements of an outlet structure may include one or more of the following: a circular orifice, a noncircular orifice, a rectangular weir, a trapezoidal weir, a triangular weir, a V-notch weir, culvert entrance control or a riser overflow opening. The V-notch weir is an efficient combination of low maintenance requirements and a wide range of flow discharges.

Figures P-02-3 and P-02-4 illustrate possible designs for the outlet structure. These details are only two possible ways to accomplish stormwater detention and stormwater quality control. The first flush volume is typically drained during a minimum time of 24 hours by using an orifice or orifices with a designed size. Maximum drain time should be less than 72 hours to allow for sufficient volume recovery prior to the next period of rainfall. Figure P-02-5 shows an alternative outlet structure with a water quality manhole.

Emergency Spillway

An emergency spillway should be included in addition to the primary outlet structure on a retention pond. The purpose of this spillway is to pass storm events that exceed the design capacity of the pond, in order to prevent overtopping the embankment. The emergency spillway should be located over undisturbed areas and <u>not</u> over the embankment fill for stability reasons. The emergency spillway capacity should be designed to prevent overtopping of the embankment structure or dam during a storm event commensurate with the impoundment volume, dam size, and downstream flood hazard potential in event of dam failure. The minimum spillway capacity should be capable of handling a 100-year storm event. The designer is referred to the requirements set forth in the Tennessee Safe Dams Act and Regulations at: www.state.tn.us/environment/permits/safedam.htm

Other Design Elements

- Sediment forebay – designed and located as pre-treatment to facilitate the cleanout of sediment, trash, debris, leaves, etc. The sediment forebay typically contains 5% to 10% of the total volume for a wet detention basin. It should be located at a point where velocities have dissipated, to allow large sediments and debris to settle out. A forebay can be separated from the remainder of a detention basin by several means: a lateral sill with rooted wetland vegetation, rock-filled gabion, rock retaining wall, or rock check dam placed laterally across the basin. The sediment

forebay should be easily accessible so that it can be inspected and maintained.

- Public safety should be considered, particularly in residential areas. Operating detention basins often attract neighborhood children. Avoid steep slopes and dropoffs; consider routes for escaping the detention basin if a person had accidentally fallen in. Provide fencing and signs in areas where children may potentially play, or in areas which have deeper water. Limit access to the outlet structure.

- Mosquitoes can be reduced by installing a steeper shelf transition at the water surface to reduce areas with water depths less than 12 inches. Small rock walls, gabions or other structures may help to create this shelf transition. Habitats for the introduction of gambusia (mosquito fish) are also beneficial if the design also includes maintaining water levels for fish survival during the dry season. Water levels also need to be maintained during winter months for fish to survive the cold weather.

- Anti-seep collars (around the outlet pipe) and cutoff clay layers (within the embankment) are usually necessary to prevent internal piping and erosion. An anti-seep collar should extend at least one pipe diameter from culvert in all directions, with compacted clay backfill using small mechanical tampers.

- To prevent the outlet riser from clogging, include trash racks or other debris barriers with a maximum opening size of 2" (and preferably 1") on all outlet structures, except for any emergency spillway structures that are designed for a 25-year storm or greater return period. Trash racks that are placed at an angle to the direction of flow are somewhat less vulnerable to clogging.

- Provide means for vehicle access to the wet detention basin. Detention basins must be located in a maintenance easement so that authorities have the right to inspect the facility. Maintenance easements that are not adjacent to a municipality's right-of-way must also have an access easement, which allows for maintenance vehicle access without large trees or excessive vehicle grades.

- Include a skimmer, oil/water separator or other type of stormwater runoff pretreatment for detention basins with greater than 50 percent impervious surface or a potential for oil and grease contamination (such as vehicle fueling and maintenance facilities, in addition to large parking areas).

- An anti-vortex device for the outlet structure may be potentially needed for very large detention basins in areas where public access is not controlled. The anti-vortex device may be a combination of vanes above the outlet structure or guide walls around the outlet structure that might increase the inlet flow efficiency, lessen the chance of humans drowning or reduce the potential for erosion and structural undercutting.

- Provide rooted vegetation at the pond perimeter, which serves several functions. Rooted vegetation enhances the removal of dissolved pollutants and reduces the formation of floating algae. It provides some habitat for insects, aquatic life, and wetland wildlife. The littoral zone for rooted vegetation should be about 10 feet wide with a water depth of 1 to 2 feet. Vegetation in general slows flow velocities and increases settling. However, large trees should be prevented from growing on the pond, especially on the embankment.

- If placement of wetland vegetation along the perimeter is not feasible, consider the use of non-rooted wetland species (i.e. floating plants). Non-rooted vegetation is actually more effective than rooted vegetation in removing dissolved nutrients and metals. Non-rooted vegetation can be placed within floating containers to facilitate periodic removal and cleaning. Another alternative is a rock filter or bed to support non-rooted vegetation (similar to design of wastewater oxidation ponds).

Construction/ Inspection Considerations

Make sure the outlet is installed as designed. Special attention should be given to the elevations of each outlet geometry change, shape of the various weirs or orifices, and installation of cut-off collars in embankments.

Maintenance

Effective and safe operation of a detention basin depends on continuous maintenance of all system components. This means that the owner should have a regular inspection program in place for checking the condition and integrity of the basin, dam, and outlet control system to prevent minor problems from becoming serious safety and operation problems. Detention basin easements and access must be considered during the planning stage in order to allow for proper inspection and maintenance.

- Inspect the wet detention basin regularly (several times a year) and particularly after heavy rainfall events. Record all observations and measurements taken. Perform any maintenance and repairs promptly. Remove debris and trash after storm events. Check outlet structure regularly for clogging.
- Remove sediment from forebay regularly to prevent resuspension or movement. The wet detention basin should be dredged or excavated when 10% of permanent pool storage volume has been lost. Sediment removal in a wet detention basin is a major effort requiring dewatering, difficult equipment access, wet soils, and some loss of wildlife and vegetation. Sediment may be permitted to accumulate if the detention basin volume has been overdesigned with adequate controls.
- Maintain a thick and healthy stand of vegetation. Mow or trim at regular intervals to encourage thick growth. Remove leaves, grass clippings, or sticks from the wet detention basin to prevent stormwater pollution. Remove trees or nuisance vegetation as necessary in order to protect embankments. Repair banks and eroded areas.
- Reduce mosquitoes as necessary. Trim vegetation or alter water surface perimeter to reduce ponded depths that are less than 12 inches. Design of the wet detention basin may include a steeper depth transition to reduce shallow water depths less than 12 inches. Gambusia (mosquito fish) can also be placed in larger ponds if water levels are maintained to insure their survival during the dry season.
- A fountain may be desirable to increase the amount of dissolved oxygen in the water. Depths greater than 12 feet may develop anaerobic conditions which is not desirable.
- If both the operational and aesthetic characteristics of a wet detention basin are not properly maintained, recognize that it will become an eyesore and a negative environmental impact. Vegetation needs to be trimmed or harvested. Ensure that repairs are made to walkways, picnic tables, signs and public recreation equipment as needed.

- Signs should be posted at detention ponds to discourage local homeowners from depositing yard trimmings, waste, and fill materials inside the basin.

Sediment Removal

A major function of stormwater treatment BMPs is to collect and remove sediments and other debris. The sediment accumulation rate is dependent on a number of factors including watershed size, facility sizing, timing and amount of upstream construction, nearby industrial or commercial activities, etc. Sediments should be identified before sediment removal and disposal is performed. Special attention or sampling should be given to sediments accumulated from industrial or manufacturing facilities, heavy commercial sites, fueling centers or automotive maintenance areas, parking areas, or other areas where pollutants are suspected. Sediment should be treated as potentially hazardous soil until proven otherwise.

Some sediment may contain contaminants for which TDEC requires special disposal procedures. Consult TDEC – Division of Water Pollution Control if there is any uncertainty about what the sediment contains or if it is known to contain contaminants. Clean sediment may be used as fill material, hole filling, or land spreading. It is important that this material not be placed in a way that will promote or allow resuspension in stormwater runoff. Some demolition or sanitary landfill operators will allow the sediment to be disposed at their facility for use as cover. This generally requires that the sediment be tested to ensure that it contains no hazardous or toxic substances.

Cost Considerations

Generally more expensive than dry ponds and biofilters.

Limitations

- A retention basin will require frequent inspection and maintenance. Trash, debris, leaves and other large items should be removed from the detention basin following each rainfall event. If upstream erosion is not properly controlled, wet detention basins can be maintenance-intensive with respect to sediment removal, nuisance odors, insects and mosquitoes, etc. Municipalities should develop clear policies on who is responsible for maintaining detention basins.
- Controlling mosquitoes and oxygen levels in retention ponds is a concern.
- A retention basin may not have sufficient vegetation on the slopes and bottom to prevent erosion and pollutant resuspension. Vegetation must be maintained and cut at adequate intervals.
- A retention basin that impounds more than 30 acre-feet of volume (and minimum 6 feet high) or which is higher than 20 feet (and minimum 15 acre-feet of volume) is subject to the Tennessee Safe Dams Act of 1973 and as amended by law. The Safe Dams Act is administered by the TDEC Division of Water Supply; further information on design standards, regulations and permit applications is available at the TDEC website:

  http://www.state.tn.us/environment/permits/safedam.htm
- Retention basins may not be feasible in very dense urban areas. Do not locate detention basins on steep unstable slopes or on shallow fractured bedrock. Impervious soils such as clay are desirable to maintain water levels during the summer or other dry periods.

Additional Information

- Retention ponds are of interest where the removal of the dissolved constituent fraction is of concern, particularly nutrients and metals. Dissolved contaminants are removed by a combination of processes: physical adsorption to bottom sediments and suspended fine sediments, natural chemical flocculation, and uptake by aquatic plants.
- Rooted vegetation around the pond perimeter serves several functions. It enhances the removal of dissolved pollutants; it may reduce the formation of floating algal mats; it reduces the risk of people falling into deeper areas of the pond; it limits erosion into the pond; and, it provides some habitat for insects, aquatic life, and wetland wildlife.
- Vegetation near the exit will assist settling of solids. An alternative is a rock filter which is used in many wastewater oxidation ponds where loss of algae in the effluent is a common problem during the growth season.
- If placement of wetland vegetation along the perimeter is not feasible, consider the use of devices that retain non-rooted wetland species. Non-rooted vegetation is more effective than rooted vegetation in removing dissolved nutrients and metals. The vegetation grows within the device, which is periodically removed and cleaned, thereby removing the contaminants from the facility.
- Because of the potential for West Nile Virus disease on permanent ponds, design and maintenance consideration should be given toward minimizing the environment for mosquito larva growth on and around the pond through frequent weed control and possible use of locally-approved larvacides such as commercially available mosquito dunks or floating Bt briquettes.

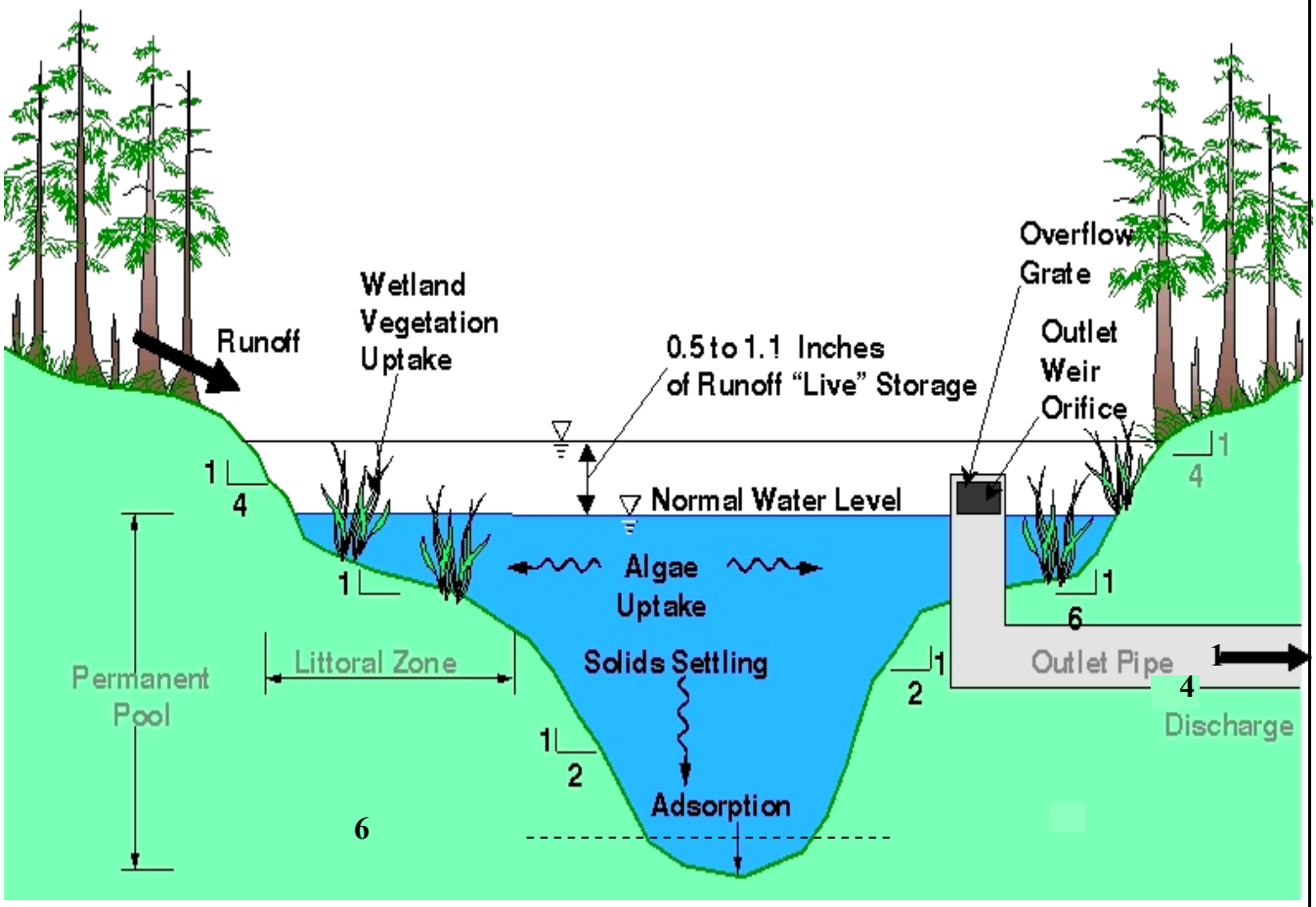
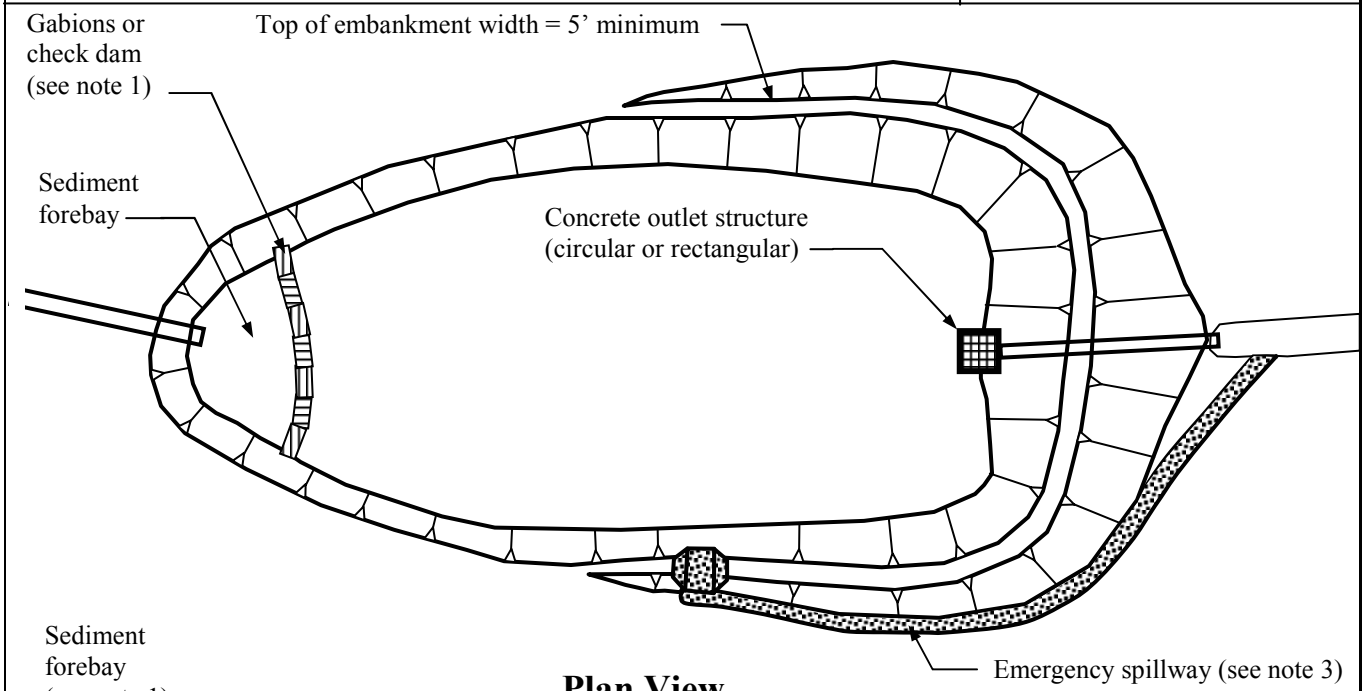
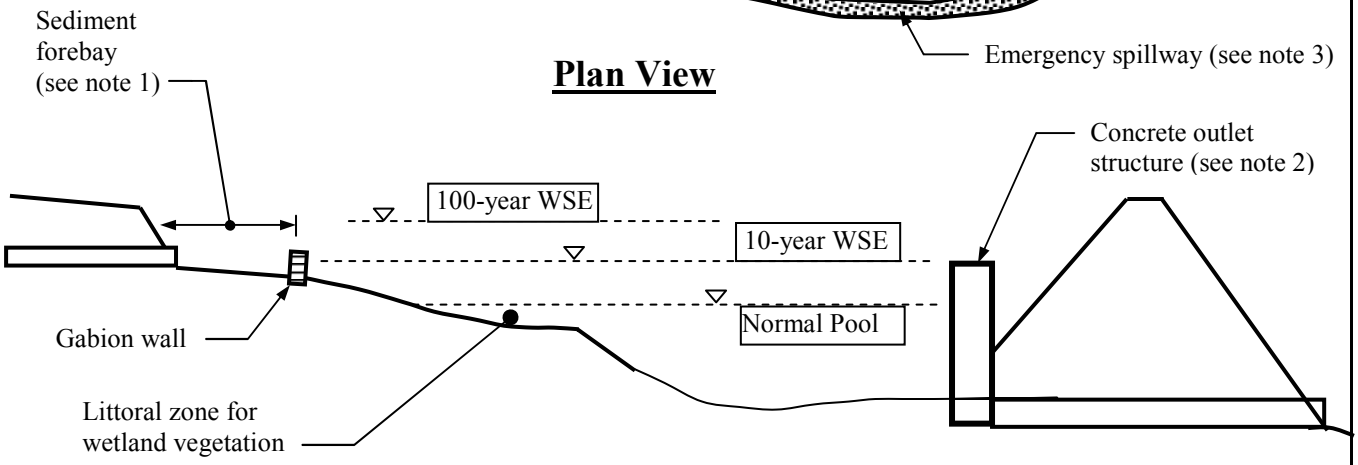


Figure P-02-1
Schematic of Wet Detention Basin



Plan View



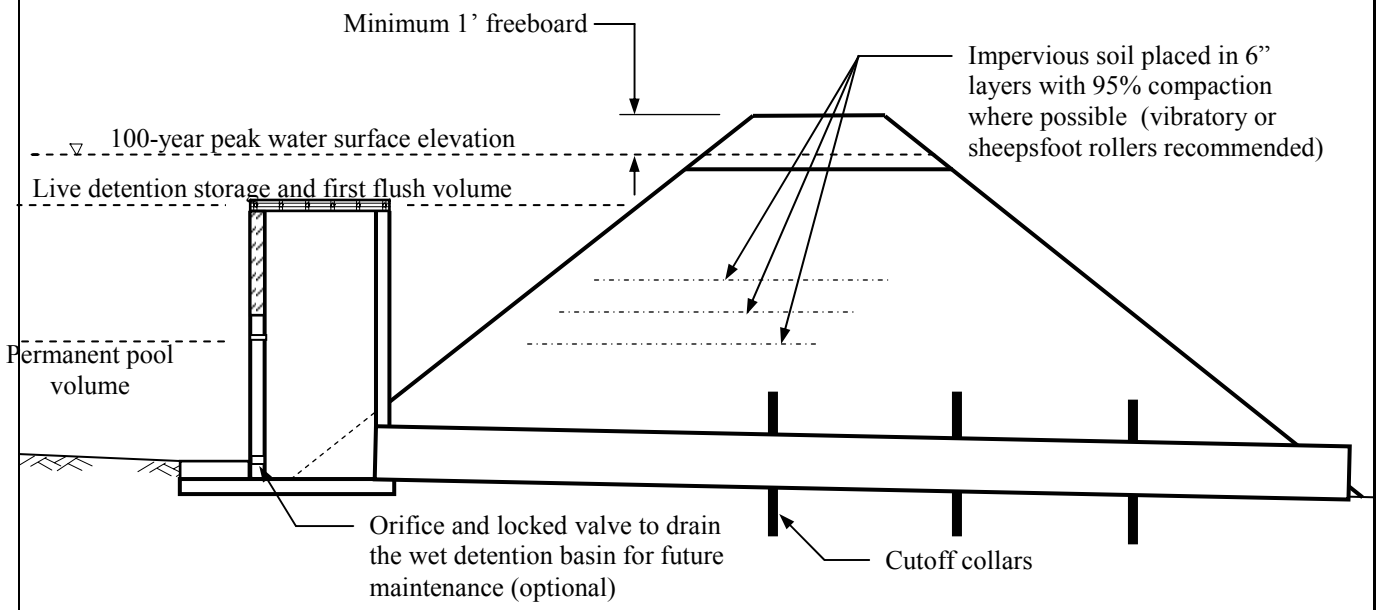
Profile View

NOT TO SCALE

Notes:

1. A sediment forebay can be constructed from gabions, rock check dams, or a separate berm with culvert. A sediment forebay can facilitate the capture and cleanup of coarse sediments, debris and trash.
2. The outlet structure typically has orifices or weirs at computed elevations that will release the 1-year, 2-year, 5-year and 10-year storms at the specified predevelopment peak flow rates.
3. The emergency spillway is generally constructed on natural ground or excavated areas (rather than fill soils) to reduce the potential for erosion and washout.

Figure P-02-2
Typical Wet Detention Basin Layout



Typical Outlet Structure (V-notch)

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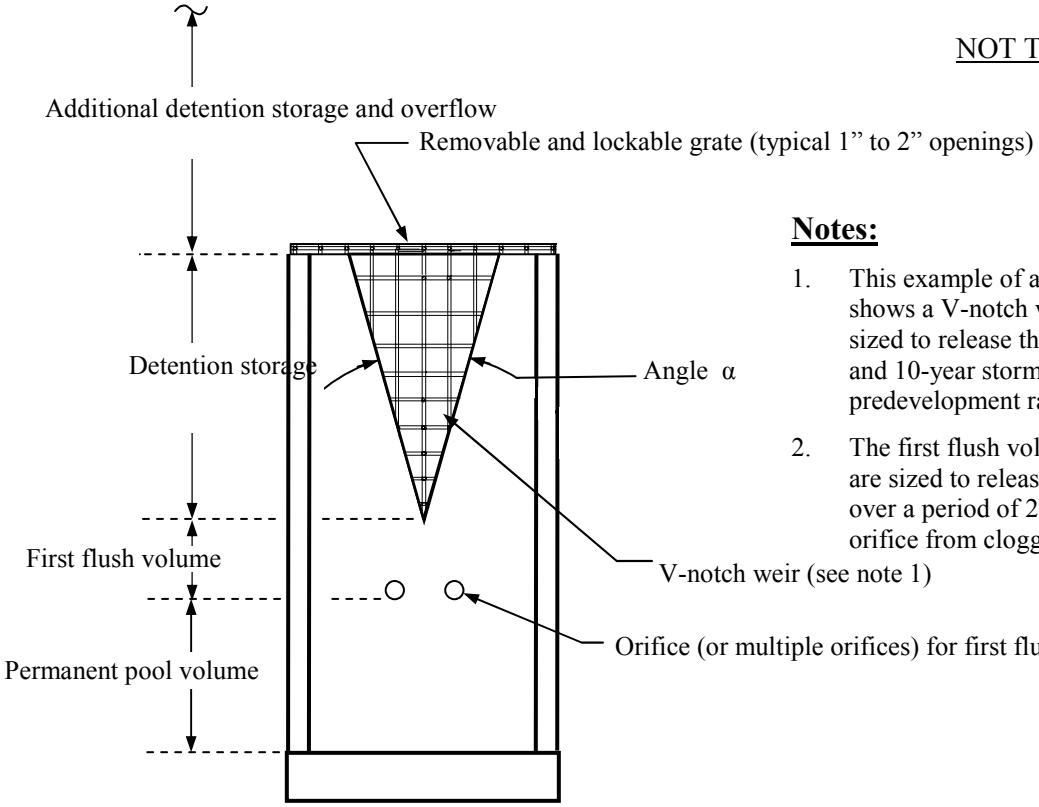
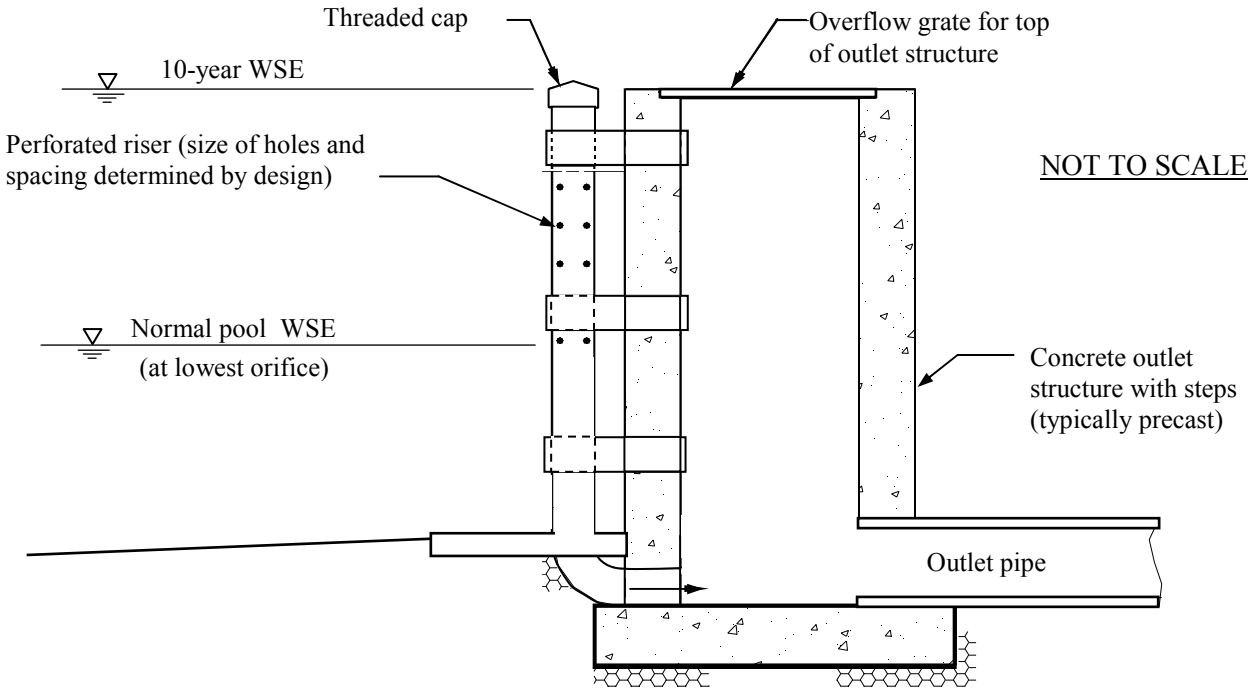


Notes:

1. This example of a typical outlet structure shows a V-notch weir which should be sized to release the 1-year, 2-year, 5-year and 10-year storm peak flows at the predevelopment rates.
2. The first flush volume orifice or orifices are sized to release the first flush volume over a period of 24 hours. Protect the orifice from clogging with a trash rack.

Figure P-02-3
Typical Outlet Structures
(shown with a V-notch weir & sand filtration box)



Note:

This type of outlet structure may be used if there is adequate protection and structural support for the perforated riser.

Figure P-02-4
Outlet Structure – Alternative A

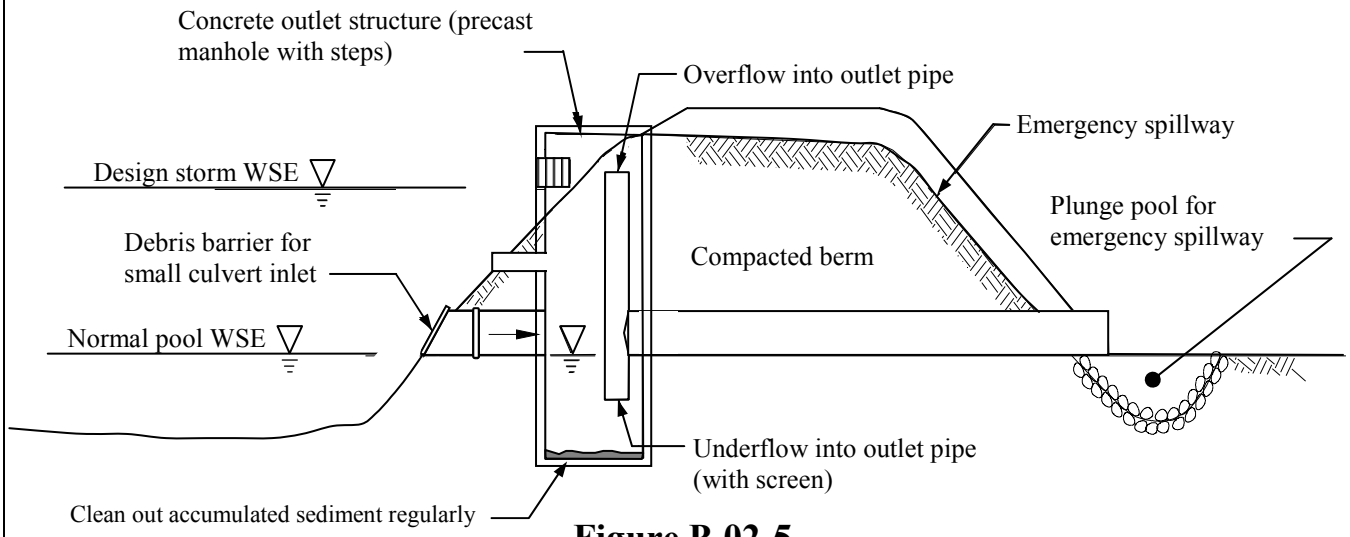


Figure P-02-5
Outlet Structure – Alternative B
(includes water quality manhole with underflow)

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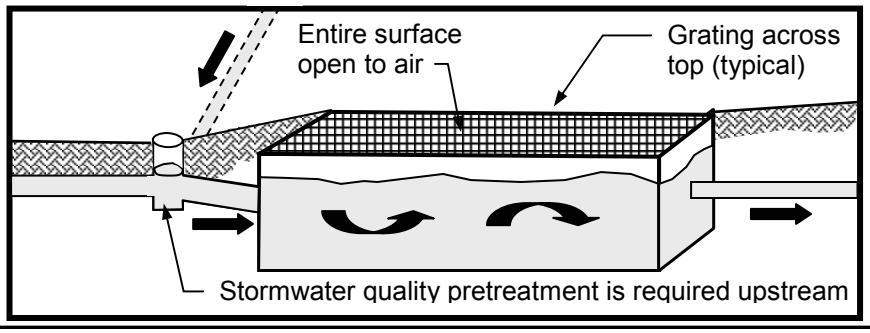
ACTIVITY: Alternative Storage Measures

P – 03



Targeted Constituents				
● Significant Benefit		◗ Partial Benefit		○ Low or Unknown Benefit
◗ Sediment	○ Heavy Metals	◗ Floatable Materials	○ Oxygen Demanding Substances	
○ Nutrients	○ Toxic Materials	○ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes
Implementation Requirements				
● High		◗ Medium		○ Low
● Capital Costs	● O & M Costs	● Maintenance	● Training	

Description

Alternative storage includes water quantity control measures such as underground detention, rooftop, or parking lot storage. These measures use structural means to provide necessary volumes for attenuating stormwater peak flows. An underground detention structure is a large underground tank that acts as a detention structure. Rooftop storage is water ponded on top of a building, to control runoff quantity from the impervious roof of a building. Parking lot storage is water detained on a parking lot along a curb. The discharge offsite can be controlled by a curb cut.

Selection Criteria

These measures are sometimes desired in areas where the cost of land is high enough to justify the additional construction, maintenance and operating costs, or where the risk to property damage is minimal. Potential applications could include very large development projects (such as regional shopping malls), for which the cost of providing alternative storage measure structures would not be prohibitive.

Design and Sizing Considerations

If designed and constructed in accordance with good engineering practices by reliable and proven contractors of local reputation, such facilities could be beneficial. The following minimum requirements must be followed in the potential design and construction of an underground detention facility:

- The entire area of the underground detention structure must be open to the air surface directly above, either with no cover or by installing continuous grates across the top. This allows for inspection and maintenance access of the entire facility with sunlight to provide the primary means of illumination. The facility will consider public safety and access (locks, fences, curbs) and is often designed to withstand truck loading such as HS-15 or HS-20.
- The underground detention structure must be constructed of durable materials with a typical 100-year lifetime. Detention storage volume shall not include the porous space within a stone or gravel bed (commonly done in many states for a series of pipes or pipe arches under parking lots).
- The underground detention structure shall be designed to have positive drainage into the receiving channel, assuming that there is a 10-year flood in the receiving

channel. This ensures that the designed volume is used for onsite detention rather than containing offsite floodwaters.

- The underground detention structure shall not receive surface runoff directly from parking lots through the top opening. Surface runoff shall be directed to a BMP that improves stormwater quality, such as an oil/water separator or grass filter strips. The underground structure will usually have a curb or other barrier around the top to prevent this.
- Design measures must be taken to trap and store sediments in locations where cleanout and maintenance can be easily performed. This generally requires that some type of water quality inlet or other stormwater treatment BMP must be installed upstream from the underground detention facility.
- Good design practices also require that structural measures shall be in place to prevent blockages. Floatable waste materials shall be collected by trash racks for periodic removal. The underground detention structure shall have a positive means of being dewatered for inspection and maintenance purposes.
- There are two primary designs for parking lot storage. One way is to pond areas along sections of curbs. Discharge is controlled by a downstream control measure such as a curb cut. The other design employs depressed areas of pavement at drop inlet locations. Discharge in both cases should be routed to a pond to remove first flush and other contaminants.
- The storage area in parking lot storage should have a minimum slope of 0.5% toward the outlet, to ensure complete drainage.
- Parking lot storage should not be located in the area of the fire lane.
- Rooftop storage can be used as a detention measure, provided the roof structure has been designed to support the additional weight of ponded water, and is sufficiently waterproofed.
- Rooftop storage measures must meet local and state codes.
- The minimum pitch on a roof subject to ponding is 0.25 inches per foot.
- The rooftop drainage system should have alternate mechanisms for draining the ponding area in case the primary outlet is clogged.

The above requirements do not allow for the use of large-diameter pipes in a gravel layer or envelope. Arch culverts filled with stone and gravel, or even masonry block structures, were frequently used to provide stormwater detention/infiltration underneath parking lots. Underground detention structures were promoted a few decades ago as a common means of detention in many areas of the country, particularly under parking lots. Most states and cities now discourage underground detention.

Construction/ Inspection Considerations

Regardless of the alternative storage measure chosen, it is essential that the BMP is constructed properly. Designed grades, materials, and compaction should be followed for these measures to function properly.

Maintenance

A detailed maintenance and inspection plan must be submitted and approved (including inspection schedules and guidelines). Evidence of responsibility and

financial budgeting must be presented, in addition to the usual bonds and agreements necessary for all detention structures.

Cost Considerations

Varies, depending on application.

Limitations

Underground detention structures are very strongly discouraged for several reasons:

- The cost of building underground structures is usually prohibitive when compared to dry detention basins, and this may cause some developers and contractors to illegally reduce detention volume or alter construction details in an effort to contain costs.
- It is very difficult to inspect underground structures, particularly if entering the structure qualifies as confined space entry (which is controlled by OSHA safety regulations). Cleanout and maintenance costs will need to be provided for and budgeted indefinitely.
- Areas with clay soils have low overall stormwater infiltration and high groundwater tables). Many parts of Tennessee have many karst and sinkhole formations, for which underground detention structures could potentially cause additional stormwater flow volumes without an adequate means of inspection.
- Underground structures may not receive enough air and proper ventilation to avoid anaerobic conditions and dangerous flow conditions.
- Stormwater runoff quality is not substantially improved or enhanced by underground detention. Underground structures do not allow grass or other vegetation to absorb nutrients, minerals or pollutants from stormwater runoff. Underground structures do not take advantage of natural stormwater infiltration into the ground surface.
- Parking lot storage should not be used when curb-high water levels are not acceptable.

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Constructed Wetlands

ACTIVITY: Constructed Wetlands

W – 01

Targeted Constituents				
● Significant Benefit		◗ Partial Benefit		○ Low or Unknown Benefit
◗ Sediment	◗ Heavy Metals	◗ Floatable Materials	◗ Oxygen Demanding Substances	
◗ Nutrients	◗ Toxic Materials	◗ Oil & Grease	◗ Bacteria & Viruses	○ Construction Wastes

Implementation Requirements			
● High		◗ Medium	○ Low
● Capital Costs	◗ O & M Costs	● Maintenance	◗ Training

Description

Constructed wetlands, or man-made marshes, may be used as a method of stormwater treatment if designed and applied correctly, and are highly desirable as wildlife habitats. Under ideal conditions, a constructed stormwater wetland can be very efficient in removing pollutants through gravitational settling, wetland plant uptake, absorption, physical filtration, and biological decomposition. The pollutant removal efficiency of a constructed wetland is dependent on various design criteria relating to the size and design of the pool area. Other site specific design features and variations in environmental conditions such as soils, climate, hydrology, etc. make it difficult to predict the actual pollutant removal efficiency. Monitoring of many stormwater wetland facilities has confirmed the wide range of pollutant removal efficiencies associated with such systems. Constructed wetlands should be used in conjunction with another BMP until firmly established and pollutant efficiency is verified. This practice is likely to provide significant reductions in most targeted constituents but may not be as reliable as other types of stormwater treatment.

Selection Criteria

The following conditions are ideal locations for constructed wetlands:

- Small outfalls for which adequate water and soil conditions will allow the establishment and permanent growth of wetland vegetation.
- Large industrial and commercial project sites with ample space, for which adequate water and soil conditions will allow the establishment and permanent growth of wetland vegetation.
- Near greenways, parks, landscaping, recreational areas or other aesthetic locations.

Both low- and high-visibility sites are suitable for constructed wetlands. However, the aesthetic problems associated with having a natural and free growing landscape feature in an otherwise manicured development setting should be avoided for high-visibility sites. Additional concerns regarding stagnation or excessive infiltration during the dry summer months may also influence the choice of location. Proper planning, design, and maintenance are critical to ensure the pollutant removal capabilities of a constructed wetland and to insure its acceptance by adjacent landowners.

Design and Sizing Considerations

The regulatory definition of a wetland is an area that is inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions, such as a swamp, marsh, bog or vernal spring.

Natural wetlands are protected and permitted by the Tennessee Department of Conservation in conjunction with the U.S. Army Corps of Engineers. Wetlands can be identified through the presence of certain plants, soil types, insects, etc., in addition to the presence of water or poor drainage. Wetlands may be seasonal, so that it can be very difficult to recognize a wetland during the summer months. Do not disturb natural wetlands without express written permission from TDEC and the U.S. Army Corps of Engineers. Visit the TDEC website for more details on how to obtain an Aquatic Resources Alteration Permit:

http://www.state.tn.us/environment/permits/index.html

In contrast, constructed wetlands are built specifically for treating stormwater runoff, and are not created as mitigation for the loss of natural wetlands. Consequently, constructed wetlands do not necessarily have to meet the stricter standards necessary to replace natural wetlands. Constructed wetlands use larger areas than other types of stormwater treatment BMPs. For small sites with advantageous water and soil conditions, concrete retaining walls can be used for one or more sides to save space. The term "constructed wetland" may also refer to a method of treating small amounts of wastewater and sanitary sewage, typically from a single residence or a small group of residences. Within the context of the BMP Manual, the term "constructed wetland" refers to the treatment of stormwater runoff only, and not for the collection and treatment of wastewater and sanitary sewage.

Constructed wetlands remove dissolved phosphorous, nitrogen, and other nutrients both directly (for aquatic plants) and through the soil (for rooted plants). In addition, wetland vegetation will uptake heavy metals, toxic materials, and other pollutants. Over long periods of time, bioaccumulation of metals such as lead or zinc have been observed in both fish and wildlife in some instances. Sediments should be removed regularly from the wetland forebay, and presence of heavy metals should be monitored. It is conjectured that the wetland soils may need to be replaced every 5 to 10 years in order to improve uptake of heavy metals and phosphorous. Cleaning the forebay and replacing bottom soils is probably adequate to collect and remove heavy metals.

A constructed wetland with additional capacity for extended detention is very similar to a wet detention basin, except with different types of vegetation. Guidelines in this BMP apply to the portion of constructed wetlands below the normal pool elevation. See P-02, Retention Basin, for typical berms, outlet structures, and grading details which are generally applicable to constructed wetlands also. An advantage of a constructed wetland, in addition to aesthetics and wildlife, is that a wetland has smaller required treatment volumes (which may be negotiable) than does a wet detention basin.

The detailed design of a constructed wetland should generally be accomplished by a team that includes a hydrologist or engineer for hydrologic/hydraulic/water balance analyses and a wetland ecology specialist for selecting vegetation and habitat parameters. In addition, a detailed subsurface report should be conducted by a qualified geotechnical engineer prior to design of the wetland. However, the following basic guidelines will assist in making preliminary plans and layouts for a constructed

wetland.

Existing Conditions

Site conditions, such as property lines, easements, utilities, structures, etc. that may impose constraints on development should be considered when designing a constructed wetland. Under no conditions, should a constructed wetland be built over an existing utility. Likewise, no utility should be permitted to construct new infrastructure in the location of an existing constructed wetland. Local government land use and zoning ordinances may also specify certain requirements.

All facilities should be a minimum of 20 feet from any structure, property line, or vegetative buffer, and 100 feet from any septic tank/drainfield. Local landuse setbacks and other restrictions may apply.

All facilities should be a minimum of 50 feet from any steep slope (greater than 10%). A site-specific geotechnical report must address the potential impact of a constructed stormwater wetland that is to be installed on, or near, such a slope.

Size

The drainage area criteria for a constructed stormwater wetland is similar to that of a retention basin. Since needs of aquatic plants limit the water depth, constructed wetlands may consume two to three times the site area compared with other stormwater quality BMPs. Therefore, the maximum watershed size depends on the available area on the site that is suitable for a constructed wetland system. The minimum watershed drainage area for constructed stormwater wetlands should be based on the watershed's hydrology and the presence of an adequate base flow to support the selected vegetation. Similar to retention basins, a drainage area of 15 to 20 acres or the presence of a dependable base flow is most desirable to maintain a healthy wetland. A clay liner may be necessary to prevent infiltration if losses are expected to be high.

The overall goal for a constructed wetland is to capture over well over 90% of the annual stormwater runoff volume for urban areas, using a design storm of 1.0 inch rainfall. For storms that are smaller than 1.0 inch of rainfall, the normal pool elevation will not be completely replaced by newer stormwater during the storm event. This means that in most instances, the average water residence time within the wetland is longer than the average time between storm events, greatly enhancing pollutant removal efficiency of the constructed wetland.

Table W-01-1
Size Criteria for Stormwater Wetlands

Surface area = percentage of area at normal water pool Elevation (without stormwater surge)

Depth range = depth from normal water pool elevation

Volume = percentage of total volume below normal water pool elevation

** The surface area of high marsh should be maximized whenever possible (depending upon the types of vegetation or fish that are selected).

A. Shallow Marsh	Surface Area	Depth Range	Approx. Volumes
Forebay	5 %	18” to 72”	10 %
High marsh	** 45 %	0” to 6”	25 %
Low marsh	40 %	6” to 18”	45 %
Deep water	5 %	12” to 48”	10 %
Micropool	5 %	18” to 72”	10 %

B. Deep Marsh	Surface Area	Depth Range	Approx. Volumes
Forebay	5 %	18” to 72”	5 %
High marsh	** 25 %	0” to 6”	10 %
Low marsh	25 %	6” to 18”	15 %
Deep water	40 %	12” to 48”	60 %
Micropool	5 %	18” to 72”	10 %

Layout

Table W-01-1 shows a basic allocation of different zones within a constructed wetland. The five zones are also shown in Figure W-01-1. Zone percentages for two basic types of wetland (designated as Shallow Marsh and Deep Marsh) can be adjusted to match the target volumes and to support various types of desired vegetation. The zone designated as high marsh (0” to 6” deep) is highly desirable; it generally contains thicker vegetation than low marsh zones. Ecological complexity is promoted by varying water depth through the vegetated area rather than keeping the depth uniform.

The length-to-width ratio of the constructed wetland should generally be at least 2:1, although a 1:1 ratio is usually acceptable with baffles, islands, internal berms or other flow barriers. Dry-weather flow paths should meander back and forth throughout the wetland, as shown in Figures W-01-1 and W-01-2, to maximize contact time with soils and vegetation. Distribute flows equally throughout the wetland and avoid dead spaces. Prevent flow shortcuts by anticipating possible locations; erosion control matting and other geotextile applications may be useful to “armor” shortcut locations.

Islands reduce the total treatment volume (below the normal pool elevation) by a small amount that is usually negligible. Overgrowth of vegetation may actually cause a more significant reduction in storage volume, and can be a factor in whether to harvest vegetation within a constructed wetland. It is important to provide plenty of shade to the wetland during the summer months, since shallow depths will generally allow the water to get warm and thus degrade the downstream environment for many cold-water fish and other organisms.

It is beneficial to incorporate cascades into the wetland layout, possibly by having more than one water surface elevation. Or a cascade can be placed on one fork of a flow path and not on another. A cascade provides aeration and increases oxygen levels in the water. Oxygen is needed for the digestion of organic nutrients and particles in the water. Cascades are aesthetically pleasing and can be fashioned in many ways.

Other layout considerations include maximum side slopes of 4H:1V and preferably side slopes which are 10H:1V or flatter. On very small facilities, retaining walls may be used to conserve space. There must be provisions for vehicle access to the forebay (which requires period cleaning) and to the micropool (which may require maintenance and water level adjustments). Provide adequate freeboard (typically 1 foot) to prevent ponding stormwater or flood damage on adjacent properties.

The forebay may be partially replaced by a baffle box, stormwater quality inlets (media filtration or oil/water separators) or other means to remove floatable debris and coarse sediments. If a detention basin is constructed upstream from the wetland, then the forebay may be eliminated altogether.

For more information on outlet structures and spillways, see P-01, Detention Basin.

Water Balance

The water balance for the constructed wetland must be examined using typical values (maximum, average, minimum) for rainfall, temperature, humidity, water table, evaporation rate, and infiltration rate. The 30-year averages, published by the National Oceanic and Atmospheric Administration, are broken down for each month of the year and represent a good starting point for water balance calculations. Evaporation rates may depend on the amount of sunlight or shade, prevailing wind directions, types of windbreaks (fences can be very beneficial) and other factors. Infiltration rates can be reduced or eliminated by using a geosynthetic liner, clay or concrete. Infiltration rates can be significant in karst areas, sinkholes, fractured bedrock, sands or gravels.

In particular, the water balance must be computed for dry-weather scenarios such as late summer and early fall. A groundwater base flow or stream base flow is very favorable but may not be present during extended periods of dry weather. Drinking water or treated process water can be added during dry weather, provided that water is dechlorinated prior to use within the wetland.

Soils

The soil must be suitable for wetland vegetation. Hydric soils (soils which are normally saturated) are preferable and can be identified by wetland experts using color and texture. If necessary, organic soils must be imported to the site and placed in areas up to 24 inches deep. The soil must have an affinity for phosphorus, for which minerals containing aluminum and iron ions are typically desirable. Do not use soils which contain large concentrations of phosphorus or heavy metals, as these soils may cause concentrations of contaminants to increase in the overlying water.

Minimize water loss by preventing infiltration through the wetland bottom. For this reason, soils with high infiltration rates are not normally suitable for constructed wetlands. Depending on the type of soil, this can be accomplished by compaction, incorporating clay into the soil, or an artificial geosynthetic liner (at least 30 mil

thickness, UV resistant, durable throughout extreme temperatures). If a clay liner is used, the following are recommended:

- A clay liner should have a minimum thickness of 12 inches.
- A layer of compacted topsoil (6 to 12 inches thick, minimum) should be placed over the liner.
- Other liners may be used if adequate documentation exists to show that the material will provide the required performance.

Using gravel as the substrate may be a suitable approach in small facilities. Because gravel is lacking in nutrients, emergent species will have to take nutrients directly from the water (Reddy and Smith, Thut). However, harvesting may be more practical if plants can be easily removed from gravel.

The geotechnical subsurface investigation should also identify the presence of any rock or bedrock layers. The excavation of rock to achieve the proper wetland dimensions and hydrology may be too expensive or difficult with conventional earth moving equipment. However, blasting may open seams or create cracks in the underlying rock that may result in unwanted drawdown of the permanent pool. Blasting of rock is not recommended unless a liner is used.

In regions where Karst topography is prevalent, projects may require a thorough soils investigation and specialized design and construction techniques. Since the presence of karst may affect BMP selection, design, and cost, a site should be evaluated during the planning phase of the project.

Vegetation

The overall design of vegetation for a constructed wetland should be performed by a qualified wetland ecologist with adequate experience and training. The wetland ecologist should also be involved during construction and installation in order to achieve best results. Basic types of wetland vegetation (also called hydrophytic vegetation or hydrophytes) can be classified as floating, emergent and submergent. Wetland vegetation species should be selected based upon stress tolerance and hardiness to seasonal variations in water availability. During periods of dry weather, there must be sufficient water to avoid complete desiccation of plant roots.

Placing rooted wetland species from nursery stock throughout the wetland can be expensive when compared to a wet detention basin. However, relying on native volunteer plants to establish themselves would delay complete coverage for several years. Delayed coverage may allow the invasion of undesirable species or dominance by one or two species (such as cattails) which tend to flourish in disturbed conditions. Vegetation can also be established by taking donor soils from existing wetlands, but the soils must be transported and handled carefully. The best times to establish vegetation are typically spring and fall.

Common wetland plants include: arrowhead, bulrush, canarygrass, cattails, duckweed, ferns, marshgrass, pond lilies, pondweed, rushes, sedges, skunk cabbage, and woolgrass. Common wetland trees include: alder, ash, cottonwood, dogwood, and some maples. Trees should not have acidic leaves (such as oak trees) or undesirable fruit or nuts. Decaying leaves and stems provide food for many types of insects and other invertebrates, which in turn become food for fish, reptiles, amphibians, and mammals. Trees provide habitats for many birds and animals. Trees also tend to

discourage migrating birds (geese and ducks) which severely degrade water quality.

It can be expected that soil adsorption will continue at a slower pace during the winter. For instance, the minimum temperature for cattails, sedges, and bulrushes to function effectively is 50°, 57° and 60° Fahrenheit, respectively. It has been observed during fall and winter months that pollutants may actually be released at a greater rate than being absorbed. The net effect over a 12-month period may be that a constructed wetland is no more effective than a wet pond, particularly with regard to the removal of dissolved phosphorus and metals.

Phosphorous removal has been observed for wastewater applications (rather than stormwater treatment) to occur during the first two or three years, but then declines thereafter and may actually become negative. This effect is thought to be the result of plants reaching maximum density, for which some researchers recommend that mature plant material should be harvested and removed from the wetlands. The uptake of heavy metals is not affected by plant density and maturity. And nitrogen removal does not degrade over time either, because it is a bacteriological process. The nitrogen removal process is very temperature-dependent and therefore much slower in winter.

Annual harvesting of rooted vegetation may or may not be practical or effective at reducing seasonal losses of nutrients and prolonging the life of the constructed wetland facility (USEPA). The benefits of harvesting may depend upon the wetland species (Suziki, Nissanka, and Kurihara). Placing rooted vegetation in gravel beds rather than soil may make harvesting practical. If harvesting is to be done, it should occur twice per season: 1) in the early summer when nutrient content in the plant material is at its peak, and 2) in the early fall as the growing season comes to a close.
Vegetation is planted only after the constructed wetland has been completely created, and then carefully surveyed and regraded. Flood for at least two weeks to ensure wet soils. Drain water from the constructed wetland 2 to 3 days prior to planting. Plant vegetation at staked locations that correspond to the proper normal pool depths. Allow water to re-flood the wetland within 24 hours after planting.

Wildlife

It is beneficial to provide wildlife habitats within and around a constructed wetland. Fences can protect a wetland from human impacts, prevent access by domestic animals such as dogs and cats, and protect children. A particular concern about constructed wetlands is that mosquitoes will breed and thrive. Many types of birds and bats are very useful in reducing mosquitoes. Fish can help to control mosquitoes if a deep pool area is included for fish to reside during dry weather. Typical measures include:

- Mix of deciduous / evergreen trees
- Shrubs, vines and hedges
- Brush piles
- Exposed trunks, snags or logs
- Islands within constructed wetland
- Birdhouses, bath houses, birdfeeders

Construction/ Inspection Considerations

Considerations to be considered during construction are as follows:

- Sometimes additional stabilization of the basin area may be necessary to ensure that the vegetation becomes established and mature prior to the erosion of the planting soil. Annual grasses may be used for this purpose. However, the specified application rates should be reduced to help prevent these grasses from competing with other plants, particularly those emerging from bulbs and rhizomes.
- Grasses should be prohibited from competing with the wetland plants.
- The soil in which the vegetation is planted should be appropriate for the wetland plants selected. Soil tests showing the adequacy of the soil, or a soil enhancement plan should be submitted with the wetland design.
- The soil substrate must be soft enough to permit easy insertion of the plants. If the basin soil is compacted or vegetation has formed a dense root mat, the upper 6 inches of soil should be disked before planting. If soil is imported, it should be laid at least 4 inches deep to provide sufficient depth for plant rooting.
- The window for transplanting emergent stock extends from early April to mid-June. Dormant rhizomes can be planted in fall or winter. To insure availability, ordering stock 3 to 6 months in advance may be necessary.
- A landscape plan should describe any special procedures for planting nursery stock. Most emergent plants may be planted in flooded or dry conditions. If planting is done in dry conditions, then instructions should be included for flooding the wetland immediately following installation.
- Proper handling of nursery stock is crucial. The roots must be kept moist to prevent damage. Plants received from the nursery will be in peat pots or bare-rooted. Bare-rooted plants will have some form of protection to keep the roots moist and may be kept for several days, but out of direct sunlight. For the maximum chance of success, all nursery stock should be planted as soon as possible. A minimum acceptable success rate of the plantings should be specified in the plan.

Maintenance

Constructed stormwater wetlands will require active management of the hydrology and vegetation during the first few years or growing seasons in order for it to achieve the performance and functions for which it was designed. Vehicular access and maneuvering room in the vicinity of a constructed wetland is necessary to allow for long-term maintenance. Constructed stormwater wetlands should be designed to duplicate the functions of natural wetlands, while allowing for ongoing maintenance. The designer faces the difficult task of replicating natural wetland hydrology in a constructed setting, while ensuring easy access for maintenance. The following criteria should be observed with regards to maintenance:

- Inspect wetlands at least twice a year and after each extreme storm event. Remove trash and foreign debris. Remove nuisance vegetation and animals if present. Repair or replace areas of erosion or damage. Check sediment deposits and remove if necessary. Clean deposits from the forebay when a loss of capacity is significant, probably every 3 to 5 years depending on the land use, or if concentrations of heavy metals or other pollutants in sediments are reaching a level of concern, typically every 5 to 10 years.
- In general, a constructed wetland should be preceded by other types of stormwater treatment BMPs to remove oil, grease, toxic sediments, heavy metals and coarse sediment. Inspect upstream controls at least twice a year and after each extreme storm event. Perform required maintenance and repairs, particularly for oil/water

separators and for media filtration inlets.

- Removal of sediment depends on the accumulation rate and available storage, in addition to other factors such as watershed size, facility sizing, construction upstream, industrial or commercial activities upstream, etc. The types of sediment should be identified before removal and disposal. Special attention or sampling should be given to sediments accumulated from industrial, manufacturing or heavy commercial sites, fueling centers or automotive maintenance areas, parking areas, or other areas where pollutants are suspected. Treat sediment as potentially hazardous soil until proven otherwise.

- The constructed wetland and its buffer may need a reinforcement planting at the onset of the second growing season after construction. The size and species of plants to be used should be based on the growth and survival rate of the existing plants at the end of their first growing season. Controlling the growth of certain invasive species, such as cattail and phragmites, may also be necessary. These plants can be very hard to contain if they are allowed to spread unchecked. The best strategy may be to design for a wide range of distinct depth zones.

- Research shows that for most aquatic plants the bulk of the pollutants is stored in the roots, not the stems and leaves). Therefore, harvesting before winter dieback is unnecessary. Many unanswered questions remain concerning the long-term pollutant storage capacity of plants.

- The embankment and BMP access road should be mowed biannually, at a maximum, to prevent the growth of trees. Otherwise, the buffer and upland areas should be allowed to grow in meadow conditions.

Cost Considerations

More expensive than a detention or retention pond.

Limitations

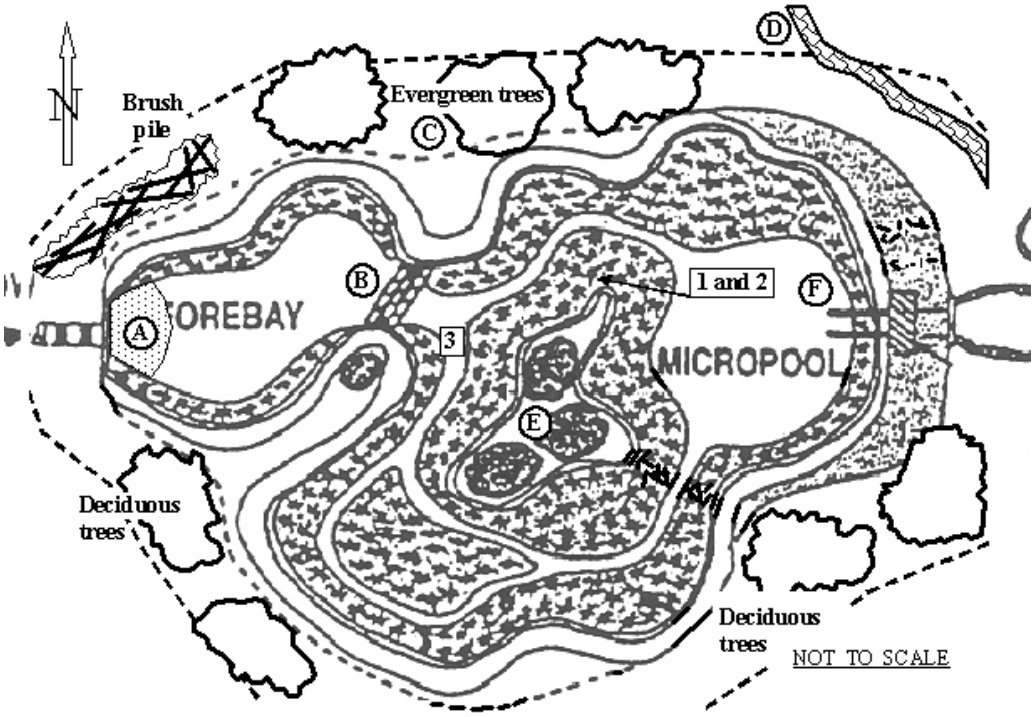
There are many limitations to the task of establishing a self-functioning ecological system such as a constructed wetland. A few limitations are listed here:

- Must have the correct soil types and the appropriate vegetation.
- Requires adequate surface area and volumes to function effectively.
- Difficult to construct and requires careful attention to detail.
- Must have adequate flow to maintain water level.
- Requires constant monitoring to remove nuisance vegetation and animals.
- Burrowing animals can damage geosynthetic liners and increase infiltration.
- Concern for mosquitoes, snakes, spiders and other undesirable wildlife.
- Biological activity decreases with seasonal cold weather, lowering pollutant removal efficiency.
- The conversion of plant species and densities as the wetland matures and becomes acclimated to various environmental factors such as soils, hydrology, climate, and sediment and pollutant load changes the performance of the wetland.
- The uncertainty of the biological cycling processes of phosphorous in the wetland environment.

Additional Information

Additional information regarding constructed wetlands are as follows:

- Constructed stormwater wetlands are generally located in areas with favorable hydrology. These locations are prone to being environmentally sensitive (low-lying) as well, and may contain existing wetlands, shallow marshes, perennial streams, wildlife habitat, etc., which may be protected by state or federal laws. The owner or designer should review local wetland maps and contact local, state, and federal permitting agencies to verify the presence of wetlands, their protected status, and the suitability of the location for a constructed wetland.
- With careful planning, it may be possible to incorporate wetland mitigation into a constructed stormwater wetland. This assumes that the functional value of the existing or impacted wetland can be identified and included, reconstructed, or mitigated for, in the stormwater wetland. Contact TDEC for more information regarding wetland mitigation.



Notes:

A. Culvert outlet velocity should be minimized using efficient design or some type of outlet protection.

B. A gabion wall or riprap berm will provide some filtering capability for removing trash, floating debris and coarse sediment. This will reduce maintenance upon vegetated portions of wetland.

C. Provide a buffer zone (typically 20' to 25') around the wetland using native trees, shrubs and grasses. Evergreen trees (also brush piles or fences) on north side will protect against winter weather. Deciduous trees on south side will provide shade in summer and sunlight in winter.

D. Post signs and place garbage cans as needed along nearby trails, sidewalks or greenways.

E. An island in the center of the wetland can provide a safe haven for wildlife or birds. The island will also prevent shortcutting of flows.

F. Provide adjustable weirs, gate valves, or other means of controlling water surface elevation for long-term operations and maintenance.

Principal zones of a wetland:

1. High marsh
2. Low marsh
3. Deep water
4. Micropool

Figure W-01-1
Typical Wetlands Layout

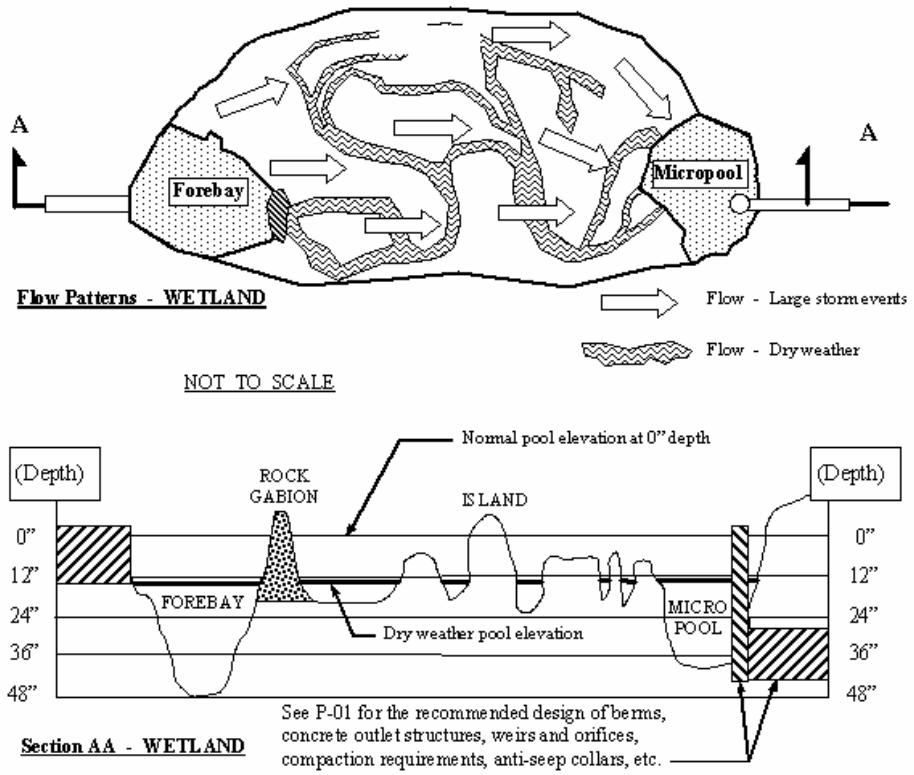
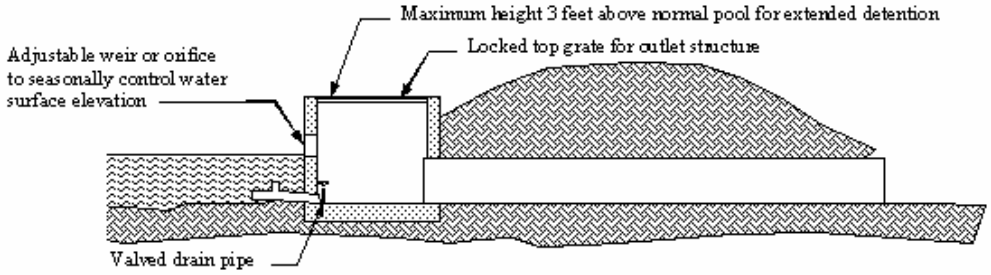


Figure W-01-2
Typical Flow Patterns



NOT TO SCALE

Figure W-01-3
Typical Outlet Structure

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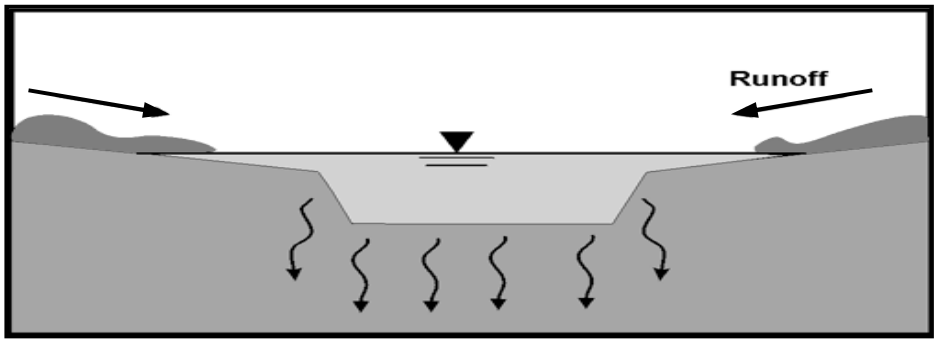
Infiltration Systems

ACTIVITY: Infiltration / Percolation Trench

I – 01



Targeted Constituents				
● Significant Benefit		◗ Partial Benefit		○ Low or Unknown Benefit
● Sediment	◗ Heavy Metals	◗ Floatable Materials	◗ Oxygen Demanding Substances	
◗ Nutrients	◗ Toxic Materials	◗ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes
Implementation Requirements				
● High		◗ Medium		○ Low
◗ Capital Costs	◗ O & M Costs	◗ Maintenance		○ Training

Description

This BMP includes the infiltration / percolation trench, in which stormwater runoff is infiltrated into a shallow, excavated trench backfilled with stone aggregate rather than discharged to a surface channel. It is located below ground or at-grade and is usually designed to accept the first flush of stormwater runoff, temporarily store it, and eventually allow it to infiltrate into the subsoil through its sides and bottom.

Infiltration rates in many areas of the state are typically poor due to clay soils and bedrock. Such locations may not be suitable of infiltration trench BMPs. Infiltration systems work best at sites having sandy loam types of soils. Areas containing karst topography and sinkholes may initially appear to have excellent infiltration, but should be considered as unreliable and will require very careful investigation and analysis.

Selection Criteria

Following are some criteria for placement of infiltration trenches:

- Infiltration trenches may be used for stormwater quality and stormwater detention at small project sites only if soil, geologic and groundwater conditions are suitable. Soils must have adequate infiltration rates as measured or tested in the field. No unfavorable geologic conditions shall be present that would indicate sinkholes or underground passageways.
- Infiltration trenches are often used in low to medium density, residential and commercial areas with limited and costly land space. They are usually used for small drainage areas of less then five acres. They require highly permeable soils and a water table depth much lower than the bottom of the trench to prevent contamination of the groundwater.
- According to the Florida Development Manual (1988), they are used to receive runoff from roof drains, parking lots, tennis courts, and roadways.
- Infiltration trenches should always be designed to have pretreatment facilities, such as a filter strip or grass swale, to aid in the removal of suspended materials, oil, grease, and other particulate pollutants.
- Natural sinkholes (or other evidences of karst topography and drainage) are not considered to be suitable locations for infiltration systems for use in treating stormwater quality or in providing stormwater detention. In general, stormwater

drainage may continue to flow to a natural sinkhole at a rate that is representative of natural undeveloped conditions. No unusual or unfavorable geologic conditions shall be present near the sinkhole that indicates subsidence, piping, increased limestone dissolution, potential collapse or other safety concerns.

Design and Sizing Considerations

Infiltration can be a very desirable method of stormwater treatment for land uses which do not heavily pollute stormwater runoff. For instance, established residential areas typically have less pollution than industrial and commercial areas. The primary physical conditions necessary for infiltration are: 1) permeable soils which have not been compacted or graded and 2) low and non-interfering groundwater tables.

Stormwater runoff from parking lots or buildings should be pretreated with a water quality enhancing inlet, oil/water separator, grass swale or other type of stormwater treatment BMPs to remove suspended materials. In addition, they should be designed to completely drain in two days or less.

Infiltration trenches are used mainly for water quality improvements and are not recommended for water quantity control because they do not reduce peak flows and runoff volumes very well. However, they can be used in conjunction with other BMPs to accomplish this task. They can also provide groundwater recharge, help maintain baseflow in nearby streams, and control localized streambank erosion. There are several methods and designs for infiltration trenches that can be found in various design manuals.

Following are some factors to consider in design:

- Infiltration trenches are not recommended for contributing watershed areas greater than five acres.
- The recommended minimum infiltration rate is at least 0.5 inches per hour, but may depend on type of infiltration system and the desired water quality treatment involved.
- Coarse soils are not as effective in filtering groundwater; therefore provide at least 6 to 8 feet separation from seasonal high groundwater for sand and gravel soils.
- The slope of the drainage area to an infiltration trench should not exceed five percent. This helps to keep runoff velocities low.
- The water table should be at least three feet below the bottom of the trench. This can be determined with soil borings taken at the site.
- The bottom of the infiltration trench should be at least four feet above the bedrock.
- Trenches can be 3 to 12 feet deep. The depth can be calculated using the infiltration rate, aggregate void space, and trench storage time. As a general rule, the side area to bottom area ratio should not exceed 4 to 1.
- The minimum trench width should be 2 feet.
- According to the Virginia Stormwater Handbook, infiltration trenches should be located 20 feet down-slope and 100 feet up-slope from building foundations.
- To help prevent premature clogging of the infiltration facility, a pretreatment facility such as a filter strip or grass swale should be installed to remove suspended

materials, oil, grease, etc. before it enters the trench. If an area is expected to have high levels of sediment input, an infiltration trench may not be recommended at all.

- The sides, top, and bottom of the infiltration trench should be lined with permeable filter fabric to protect the soil from contamination.
- Perforated underdrain pipes are often installed to collect the runoff and divert it to an outflow facility.
- An infiltration trench should be designed to completely drain two days after the design storm event. This allows the underlying soil to dry between storm events.
- A factor of safety should be incorporated into the design to ensure that the system still works even when partially clogged.
- It is recommended that an observation well be installed in every infiltration trench. The water levels measured in these wells can be used to monitor clogging potential and de-watering times.
- An infiltration trench can be effective year-round as long as the surface is cleared of snow and ice. If the surface freezes, its infiltration abilities are greatly impaired.
- A clean washed aggregate should be used to backfill an infiltration trench. The diameter of the aggregate should be between 1.5 and 3.5 inches. Void space is assumed to be between 30 and 40 percent.
- Infiltration trenches easily fit into the margins and perimeters of a development site and are often used in areas with little land space available. However, because the soils in developed areas are often unsuitable for infiltration trenches, the proper soil tests must be performed to determine the retrofit capability.

Overview of Infiltration Theory

The overall degree of water quality treatment achieved by infiltration is a function of the amount of stormwater that is captured and infiltrated over time. Minimum infiltration storage is generally required to be the first flush volume.

Typical infiltration rates are shown in Table I-01-1. The USDA soil texture classification is based upon the soils triangle shown in Figure I-01-1, with the following definitions:

	Approximate size	Rough description
Gravel	> 2 mm	> No. 8 sieve or so
Sand	0.05 mm to 2 mm	> No. 200 sieve
Silt	0.002 mm to 0.05 mm	Little plasticity or cohesion
Clay	< 0.002 mm	Can be rolled and compressed

Another well-known method of categorizing soils and evaluating soil properties is by the Unified Soil Classification System (USCS). The following soil groups are generally acceptable as good soils for infiltration:

SW	Well-graded sands and gravelly sands, little or no fines
SP	Poorly graded sands and gravelly sands, little or no fines

SM Silty sands, sand-silt mixtures

Table I-01-1
Typical Infiltration Rates from USDA Soil Texture

	USDA Soil Texture	Typical Water Capacity (inches per inch of soil)	Typical Infiltration Rate (inches per hour)	Hydrologic Soil Group
*	Sand	0.35	8.27	A
**	Loamy sand	0.31	2.41	A
**	Sandy loam	0.25	1.02	B
**	Loam	0.19	0.52	B
	Silt loam	0.17	0.27	C
	Sandy clay loam	0.14	0.17	C
	Clay loam	0.14	0.09	D
	Silty clay loam	0.11	0.06	D
	Sandy clay	0.09	0.05	D
	Silty clay	0.09	0.04	D
	Clay	0.08	0.02	D

* - Suitable for infiltration with typical 6’ to 8’ separation from seasonal high groundwater
** - Suitable for infiltration with at least 3’ separation from seasonal high groundwater

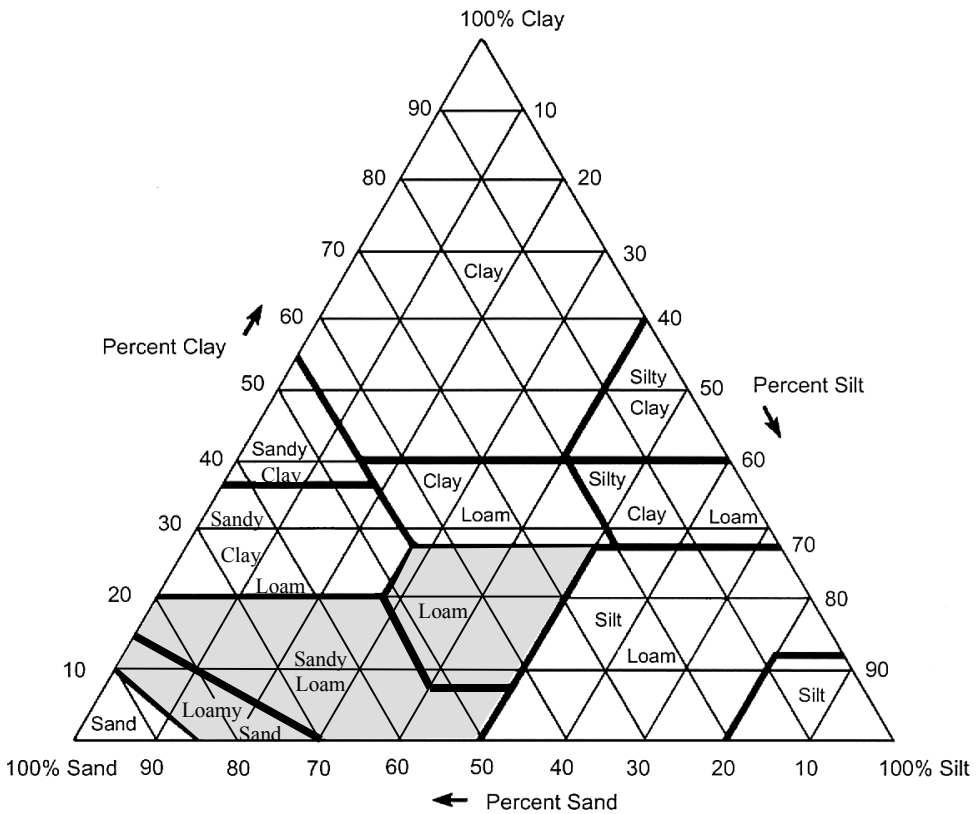


Figure I-01-1
USDA Soils Triangle

Part of the stormwater runoff storage in an infiltration trench is located within a gravel trench. The volume available for water storage is found by multiplying the total gravel volume by the porosity (η). Typical details for an infiltration trench are shown in Figure I-01-2 (for surface drainage) and Figure I-01-3 (for roof drainage). The bottom of the infiltration trench should be located at least 3 feet above the seasonal high groundwater table. There are provisions for emergency overflow in both details.

At a minimum, the infiltration trench should have adequate volume to treat the first flush. Infiltration trenches may be used around the perimeter of parking lots, between subdivision lots, or along medians or roadside swales. An infiltration trench does not have organic soil layers or surface vegetation to trap some types of pollutants. A trench may be ineffective for soluble pollutants such as hydrocarbons, nitrates, salts or organic compounds.

Infiltration trenches may be used for stormwater quality and stormwater detention at small project sites only if soil, geologic and groundwater conditions are suitable. Soils must have adequate infiltration rates as measured or tested in the field. No unfavorable geologic conditions shall be present that would indicate sinkholes or underground passageways. Unless adequate engineering documentation is submitted, an infiltration trench must be located at least 100 feet away from any drinking water well, septic tank or drainfield. It is also recommended that an infiltration trench should not be located near building foundations, buildings with basements or crawl spaces, major roadways, wetlands, streams, or potentially unstable slopes and hillsides.

Infiltration trenches are not effective in some parts of Tennessee due to clay soils and shallow bedrock conditions. Avoid steep slopes or other geologic conditions that could potentially be made unstable by infiltrating water into the ground.

Natural Depressions, Sinkholes, and Karst Topography

Much bedrock in Tennessee is composed of fractured limestone formations that are likely to contain unusual strike angles and/or nonconformities. Karst topography is defined as the presence of limestone or other soluble geology that is likely to form caverns, sinkholes, or other dissolved formations. A sinkhole is a surface depression, typically linked to an underground cavern system, which occurs primarily in limestone regions. See Figure I-01-4 for a typical sketch of a sinkhole.

For natural depressions and sinkholes, it is generally required that the post-developed peak flows and total stormwater runoff volume must be limited to the pre-developed values. In addition, it may be required that no structures will be flooded from a 100-year storm assuming plugged conditions (zero outflow). It is greatly desired that runoff should be treated using one or more stormwater treatment BMPs, prior to discharging toward a sinkhole or other natural depression.

Consideration may be given to recommendations that are based upon advanced subsurface testing or visual inspection by experts or professional engineers with demonstrated experience in hydrogeology. Tennessee Department of Environment and Conservation (TDEC) requires anyone who performs a dye trace study to obtain a TDEC registration for this activity (see TDEC website). Major sinkholes are considered to be waters of the state; filling or otherwise altering a large sinkhole requires an Aquatic Resources Alteration Permit from TDEC.

Construction/ Inspection Considerations

- It is very important to protect the natural infiltration rate by using light equipment and construction procedures that minimize compaction. Stormwater must be allowed to enter the facility until all construction in the catchment area is completed and the work area is stabilized. If this prohibition is not feasible in particular situations, do not excavate the facility to final grade until after all construction is complete upstream. With trenches, make sure the rock fill does not become dirty while temporarily stored at the site.
- Protect infiltration surface during construction.
- An infiltration trench should have an observation and sampling port, to assist in cleanout and to check water quality and groundwater levels.
- Geotextile fabric should be selected on the basis of durability, with an adequate opening size to resist clogging.
- Use clean washed aggregate (little or no fines).
- If the bottom of the trench has been compacted due to construction vehicles or other means, it should be rototilled to replenish its infiltration capacity.
- Protect the area from heavy equipment and traffic by physical means.

- Improperly functioning infiltration trenches must be replaced by other stormwater treatment BMPs that are capable of providing water quality treatment.

Maintenance

- Inspect and observe the infiltration system several times during the first year, particularly after heavy rainfall events. Use observation wells and cleanout ports to monitor water levels and drawdown times. Record all observations and measurements taken. Perform any maintenance and repairs promptly.
- Inspect the infiltration system annually thereafter, and after extreme rainfall events. If stormwater does not infiltrate within 48 hours after a storm, it is generally time to clean, repair or replace the facility. Remove debris and sediment at least annually to avoid high concentrations of pollutants and loss of infiltration capacity.
- The primary objective of maintenance and inspection activities is to ensure that the infiltration facility continues to perform as designed. Regular inspection can substantially lengthen the required time interval between major rehabilitations.
- Prevent compaction of the infiltration surfaces by physical controls such as gates or fences. Maintain dense grass vegetation for infiltration basins. Use rotary tillers on infiltration surfaces when needed to restore infiltration capacity and to control weed growth.
- Maintenance considerations should include the possibility of replacing an infiltration trench every 5 years, as the gravel and geotextile fabric will eventually become clogged and cease to function. Clogging may also occur at the bottom of the trench, along the gravel / soil interface. Clogging will occur even faster if there are fine silts, oil and grease, fertilizers and other materials present in stormwater runoff. Do not allow trees or other woody vegetation to become rooted along an infiltration trench. Inspect operation and recovery of infiltration trench at least a few times a year.
- Pretreatment of stormwater runoff may reduce maintenance costs by capturing coarse sediments and floatable materials in a smaller structure that can be more easily cleaned. All infiltration trenches should be inspected several times the first year and at least twice a year thereafter.
- Maintain records of inspections and maintenance performed.

Sediment Removal

A primary function of stormwater treatment BMPs is to collect and remove sediments. The sediment accumulation rate is dependent on a number of factors including watershed size, facility sizing, upstream construction, nearby industrial or commercial activities, etc. Sediments should be identified before sediment removal and disposal is performed. Special attention or sampling should be given to sediments accumulated from industrial or manufacturing facilities, heavy commercial sites, fueling centers or automotive maintenance areas, parking areas, or other areas where pollutants are suspected. Treat sediment as potentially hazardous soil until proven otherwise.

Some sediment may contain contaminants for which TDEC requires special disposal procedures. Consult TDEC – Division of Water Pollution Control if there is any uncertainty about what the sediment contains or if it is known to contain contaminants. Clean sediment may be used as fill material, hole filling, or land spreading. It is important that this material not be placed in a way that will promote or allow resuspension in stormwater runoff. Some demolition or sanitary landfill operators will allow the sediment to be disposed at their facility for use as cover. This generally requires that the sediment be tested to ensure that it is innocuous.

Cost Considerations

Infiltration trenches are often the most cost-effective choice for small areas where pond systems can not be installed. Pretreatment will reduce maintenance costs by capturing gross settleable solids and floatables in a smaller space that can be more easily cleaned.

Construction costs include clearing, grading, excavation, placement of the filter fabric, placement of the stone aggregate, installation of the monitoring well, and establishment of a vegetated buffer strip. Infiltration trench construction costs will vary around $7,000 - $8,000 depending on the site constraints (Schueler, 1987).

Limitations

Maintenance activities include inspection, maintaining the pretreatment facility, mowing, buffer maintenance, tree pruning or removal, sediment removal, and eventual rehabilitation. The costs of these activities vary from place to place.

- The four major concerns with infiltration trenches are clogging, potential impact on other structures and properties, accumulation of heavy metals, and the potential for groundwater contamination.
- Clogging and high maintenance costs are very likely to occur in fine soils that are marginally allowable for infiltration rates. Erosion control is extremely important to prevent clogging; infiltration trenches fail if they receive high sediment loads. Perform regular maintenance and inspections to minimize the potential for clogging and loss of infiltration capacity. Pretreatment is highly recommended for stormwater runoff from many land uses, prior to discharging to an infiltration trench.
- Infiltration trenches are not appropriate for areas with high groundwater tables, steep slopes, lots of underground infrastructure, and nearby buildings.
- Infiltration trenches tend to fail very easily and have short life spans. This is due to premature clogging of the facility, low permeable soils, and high water table. Approximately fifty percent of infiltration trenches have partially or completely failed within five years (Schueler et al, 1992).
- There are many restrictions on the use of infiltration trenches, including soil type, depth to water table and bedrock, slopes, and contributing watershed area. Careful investigations of these conditions must be performed to determine if an infiltration trench is best suited to the location over another BMP.
- Heavy metals are likely to settle in any of the stormwater treatment BMPs, but particularly for infiltration trenches (which have the lowest velocity). High

levels of heavy metals have been observed in other states where adequate maintenance was not performed. Toxic levels are not likely to be exceeded, but the sediments will need to be handled as hazardous waste after a few years of neglect.

- There is a higher risk of groundwater contamination in very coarse soils. It is highly recommended that a monitoring and inspection program should be used to verify that no contamination occurs. Infiltration trenches may not be appropriate where there is significant potential for hazardous chemical spills, or near drinking water wells.

- The use of infiltration trenches is very limited in ultra-urban areas because of unsuitable soils.

Additional Information

- Infiltration trenches are generally suitable only for small sites of a few acres.
- Infiltration trenches or wet detention should be considered where dissolved pollutants discharging to surface waters are of concern. However, satisfactory removal efficiencies require soils that contain loam. Coarse soils are not effective at removing dissolved pollutants and fine particulates before the stormwater reaches the ground water aquifer.
- Problems can be expected with infiltration trenches placed in finer soils. The State of Maryland has emphasized these systems for about 10 years where they have been installed in soils with infiltration rates as low as 0.27 inches (0.69 cm) per hour. A recent survey (Lindsey, et al., 1991) found that a third of the facilities examined (177) were clogged and another 18% were experiencing slow infiltration.
- Based on a review of several studies of infiltration facilities in sandy and loamy soils, it has been concluded that "monitoring . . . has not demonstrated significant contamination . . . although highly soluble pollutants such as nitrate and chloride have been shown to migrate to ground water" (USEPA, 1991). However, pollution has been found in ground water where infiltration devices are in coarse gravels (Adophson, 1989; Miller, 1987).
- Clogging has not been a problem with well maintained systems discharging to sands and coarser soils, suggesting that pretreatment for these infiltration devices in the aforementioned soil conditions is not necessary. Pretreatment when infiltrating to finer soils is suggested. An infiltration facility sized only for treatment is much smaller than one sized for flood control and therefore may be more susceptible to clogging.
- For small systems treating less than a few acres of pavement, pretreatment can be accomplished with a stormwater quality inlet, catch basin and a submerged outlet. The diameter and depth of the sump should be at least four times the diameter of the outlet pipe to the infiltration system (Lager, et al., 1977). Swales can also be used although they will not likely be feasible in industrial sites that tend to be fully utilized.

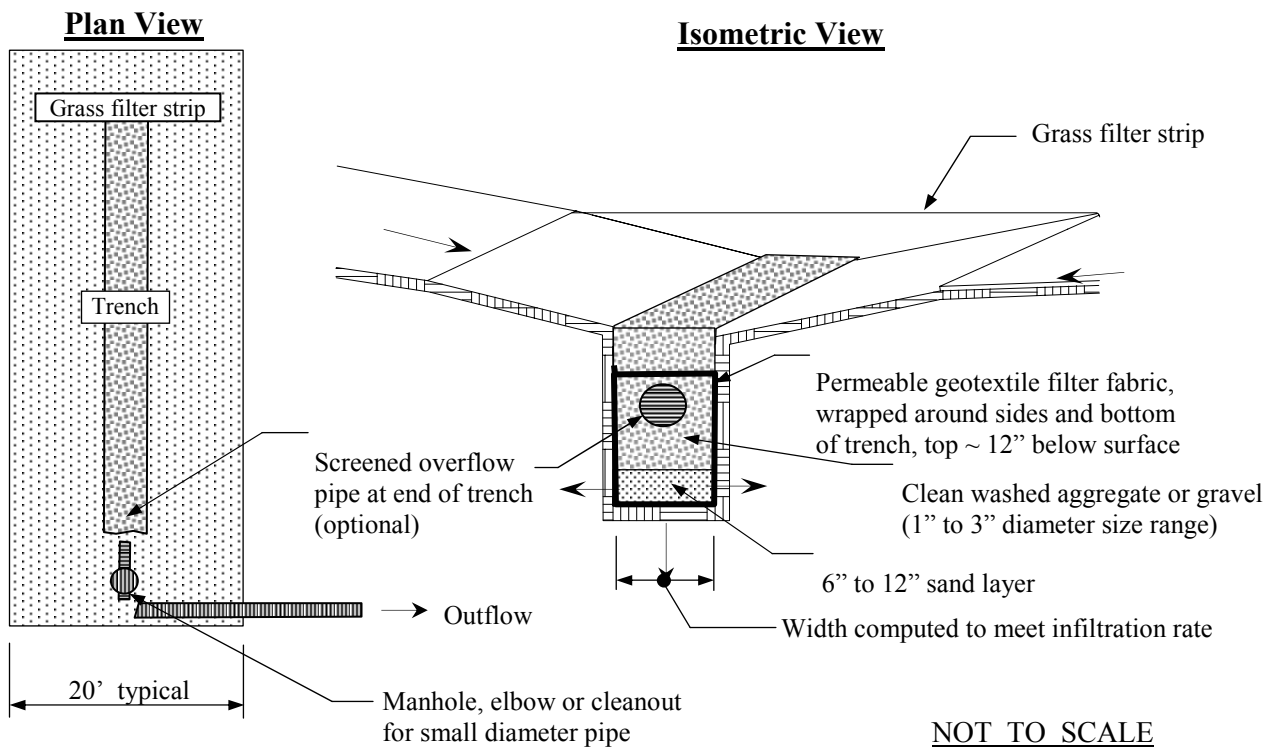


Figure I-01-2
Typical Infiltration Trench (With Surface Drainage)

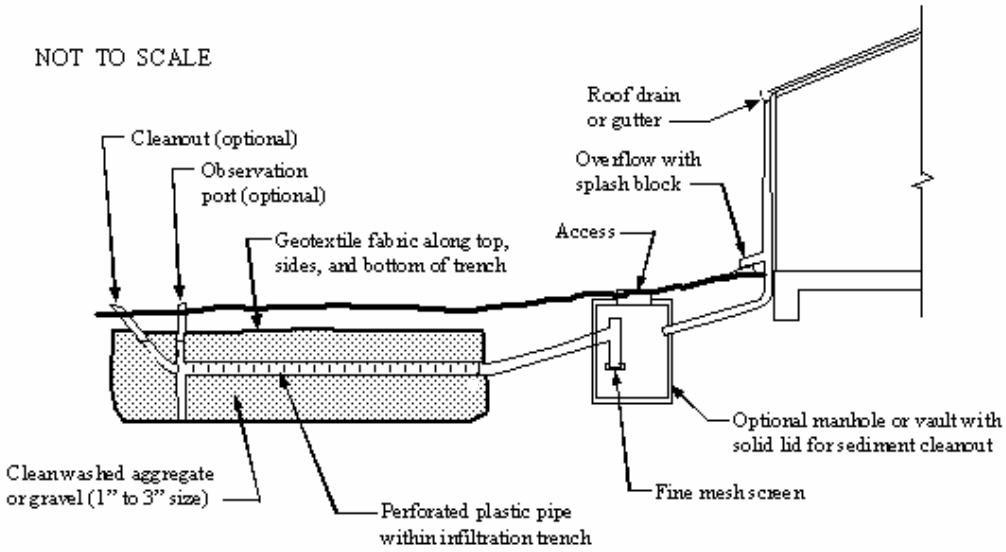


Figure I-01-3
Typical Infiltration Trench (With Rooftop Drainage)

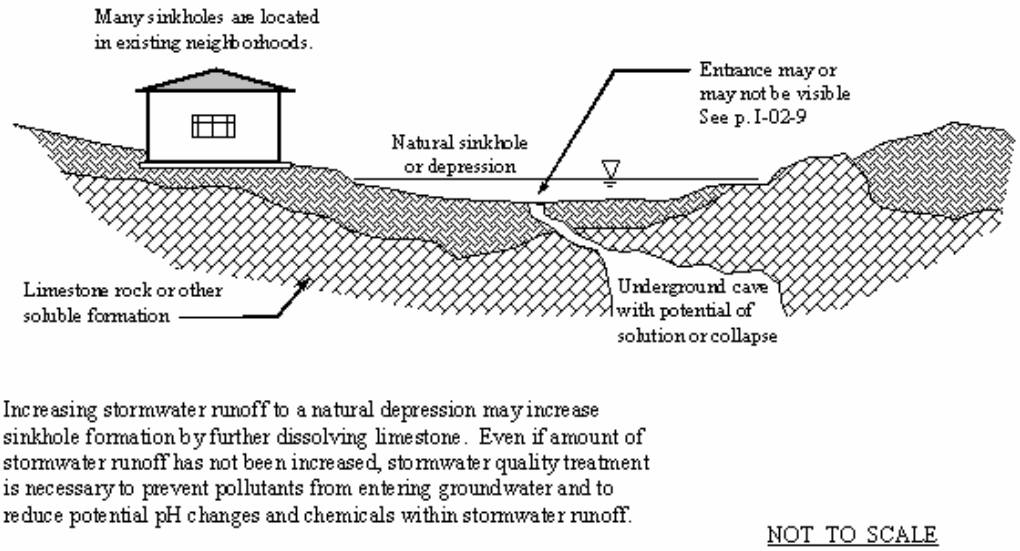


Figure I-01-4
Typical Schematic of Sinkholes and Karst Areas

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ACTIVITY: Infiltration Basin

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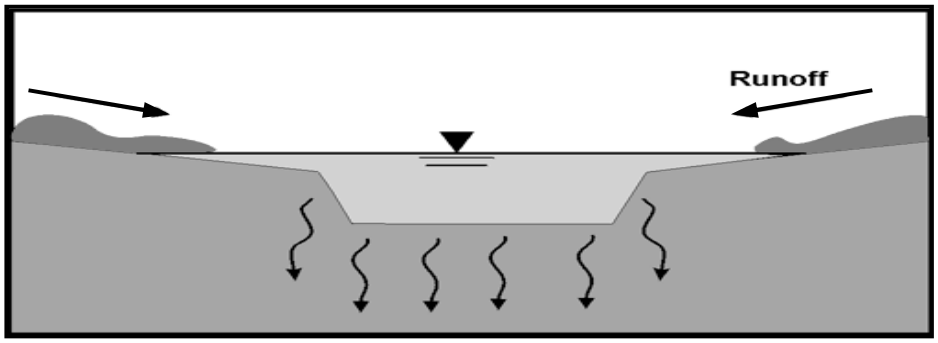

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Implementation Requirements				
● High		◗ Medium	○ Low	
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Description

This BMP covers the infiltration basins, in which stormwater runoff is infiltrated into an excavated pond rather than discharged to a surface channel. Much of the information and design characteristics are similar to that of an infiltration trench. The reader is referenced to section I-01, Infiltration/Percolation Trench, for more information. It is usually designed to accept the first flush of stormwater runoff, temporarily store it, and eventually allow it to infiltrate into the subsoil through its sides and bottom. Infiltration rates in many areas of the state are typically poor due to clay soils and bedrock. Such locations may not be suitable of infiltration trench BMPs. Infiltration systems work best at sites having sandy loam types of soils. Areas containing karst topography and sinkholes may initially appear to have excellent infiltration, but should be considered as unreliable and will require very careful investigation and analysis.

Selection Criteria

Following are some criteria for placement of infiltration basins:

- Infiltration basins may be used for stormwater quality and stormwater detention at project sites up to 50 acres in size, only if soil, geologic and groundwater conditions are suitable. Soils must have adequate infiltration rates as measured or tested in the field. No unfavorable geologic conditions shall be present that would indicate sinkholes or underground passageways.
- Infiltration basins are often used in low to medium density, residential and commercial areas with limited and costly land space. They are usually used for small drainage areas of less then five acres. They require highly permeable soils and a water table depth much lower than the bottom of the basin to prevent contamination of the groundwater.
- Infiltration basins should always be designed to have pretreatment facilities, such as a filter strip or grass swale, to aid in the removal of suspended materials, oil, grease, and other particulate pollutants.
- Natural sinkholes (or other evidences of karst topography and drainage) are not considered to be suitable locations for infiltration systems for use in treating stormwater quality or in providing stormwater detention. In general, stormwater drainage may continue to flow to a natural sinkhole at a rate that is representative of natural undeveloped conditions. No unusual or unfavorable geologic conditions

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Design and Sizing Considerations

Infiltration can be a very desirable method of stormwater treatment for land uses which do not heavily pollute stormwater runoff. For instance, established residential areas typically have less pollution than industrial and commercial areas. The primary physical conditions necessary for infiltration are: 1) permeable soils which have not been compacted or graded and 2) low and non-interfering groundwater tables.

Stormwater runoff from parking lots or buildings should be pretreated with a water quality enhancing inlet, oil/water separator, grass swale or other type of stormwater treatment BMPs to remove suspended materials. In addition, they should be designed to completely drain in two days or less.

Infiltration basins can be used for water quantity control, provided that the basin is properly maintained. They can also provide groundwater recharge and help maintain baseflow in nearby streams. There are several methods and designs for infiltration basins that can be found in various design manuals.

Following are some factors to consider in design:

- The recommended minimum infiltration rate is at least 0.5 inches per hour, but may depend on type of infiltration system and the desired water quality treatment involved.
- Coarse soils are not as effective in filtering groundwater; therefore provide at least 6 to 8 feet separation from seasonal high groundwater for sand and gravel soils.
- A maximum side slope of 3:1 (H:V) is recommended to provide bank stabilization and easier mowing.
- The slope of the drainage area to an infiltration basin should not exceed five percent. This helps to keep runoff velocities low.
- The water table should be at least three feet below the bottom of the basin. This can be determined with soil borings taken at the site.
- The bottom of the infiltration basin should be at least four feet above the bedrock.
- Basins can be 3 to 12 feet deep. The depth can be calculated using the infiltration rate, aggregate void space, and basin storage time.
- Infiltration basins should be located 20 feet down-slope and 100 feet up-slope from building foundations.
- To help prevent premature clogging of the infiltration facility, a pretreatment facility such as a filter strip or grass swale should be installed to remove suspended materials, oil, grease, etc. before it enters the trench. If an area is expected to have high levels of sediment input, an infiltration trench may not be recommended at all.
- The sides, top, and bottom of the infiltration basin should be vegetated to protect from erosion.
- An infiltration basin should be designed to completely drain two days after the

design storm event. This allows the underlying soil to dry between storm events.

- A factor of safety should be incorporated into the design to ensure that the system still works even when partially clogged.
- The water levels measured in these wells can be used to monitor clogging potential and de-watering times.
- An infiltration basin can be effective year-round as long as the surface is cleared of snow and ice. If the surface freezes, its infiltration abilities are greatly impaired.
- If the infiltration basin is to be used for stormwater detention, the designer should take infiltration rates into account when designing outlet structure elevations and sizes.
- The design of the infiltration basin should be very similar to that of a detention pond. See P-01, Detention Basin, for more information.

Overview of Infiltration Theory

The overall degree of water quality treatment achieved by infiltration is a function of the amount of stormwater that is captured and infiltrated over time. Minimum infiltration storage is generally required to be the first flush volume.

Typical infiltration rates are shown in Table I-02-1. The USDA soil texture classification is based upon the soils triangle shown in Figure I-02-1, with the following definitions:

	Approximate size	Rough description
Gravel	> 2 mm	> No. 8 sieve or so
Sand	0.05 mm to 2 mm	> No. 200 sieve
Silt	0.002 mm to 0.05 mm	Little plasticity or cohesion
Clay	< 0.002 mm	Can be rolled and compressed

Another well-known method of categorizing soils and evaluating soil properties is by the Unified Soil Classification System (USCS). The following soil groups are generally acceptable as good soils for infiltration:

SW	Well-graded sands and gravelly sands, little or no fines
SP	Poorly graded sands and gravelly sands, little or no fines
SM	Silty sands, sand-silt mixtures

Table I-02-1
Typical Infiltration Rates from USDA Soil Texture

	USDA Soil Texture	Typical Water Capacity (inches per inch of soil)	Typical Infiltration Rate (inches per hour)	Hydrologic Soil Group
*	Sand	0.35	8.27	A
**	Loamy sand	0.31	2.41	A
**	Sandy loam	0.25	1.02	B
**	Loam	0.19	0.52	B
	Silt loam	0.17	0.27	C
	Sandy clay loam	0.14	0.17	C
	Clay loam	0.14	0.09	D
	Silty clay loam	0.11	0.06	D
	Sandy clay	0.09	0.05	D
	Silty clay	0.09	0.04	D
	Clay	0.08	0.02	D

* - Suitable for infiltration with typical 6' to 8' separation from seasonal high groundwater
** - Suitable for infiltration with at least 3' separation from seasonal high groundwater

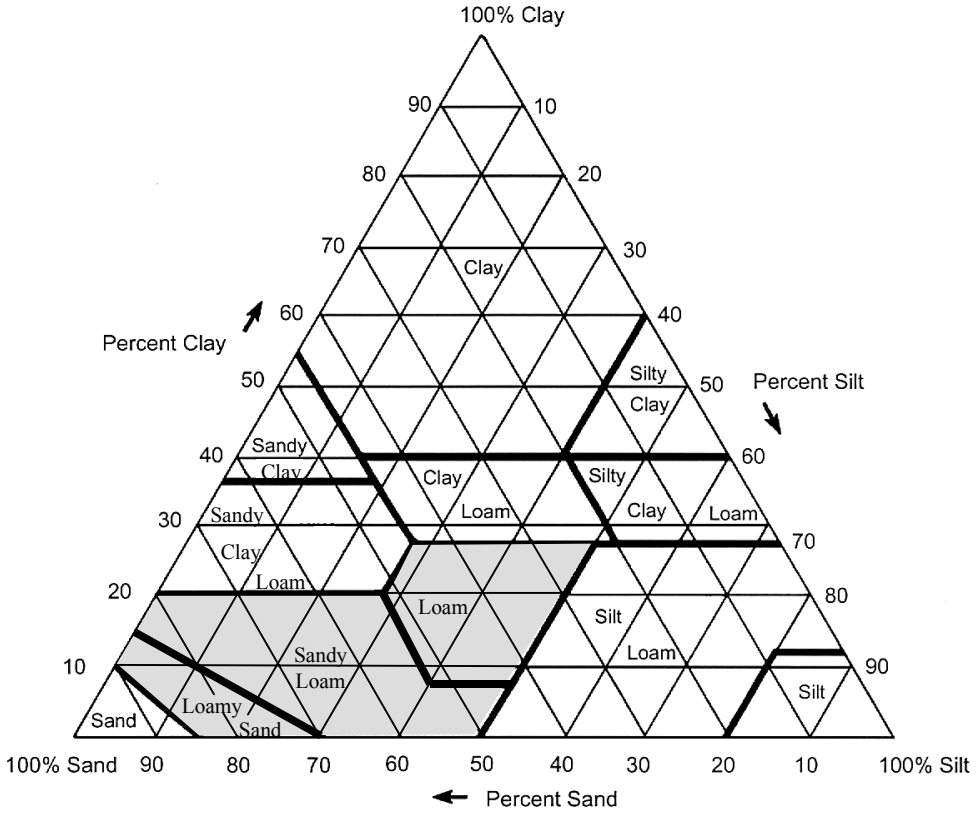


Figure I-02-1
USDA Soils Triangle

Part of the stormwater runoff storage in an infiltration trench is located within a gravel trench. The volume available for water storage is found by multiplying the total gravel volume by the porosity (η). Typical details for an infiltration basin are shown in Figure I-02-2. Pretreatment is highly recommended for areas with fine grained soils, dust, sediment, debris, or other materials with the potential to clog the soils of an infiltration basin. Design an emergency overflow of a bypass for larger storms (using overland relief swales or possibly even street drainage in the case of 100-year floods).

At a minimum, the infiltration basin should have adequate volume to treat the first flush. An infiltration basin does not have organic soil layers or surface vegetation to trap some types of pollutants. A basin may be ineffective for soluble pollutants such as hydrocarbons, nitrates, salts or organic compounds.

Infiltration basins may be used for stormwater quality and stormwater detention at small project sites only if soil, geologic and groundwater conditions are suitable. Soils must have adequate infiltration rates as measured or tested in the field. No unfavorable geologic conditions shall be present that would indicate sinkholes or underground passageways. Unless adequate engineering documentation is submitted, an infiltration basin must be located at least 100 feet away from any drinking water well, septic tank or drainfield. It is also recommended that an infiltration basin should not be located near building foundations, buildings with basements or crawl spaces, major roadways, wetlands, streams, or potentially unstable slopes and hillsides.

Infiltration basins are not effective in some parts of Tennessee due to clay soils and shallow bedrock conditions. Smaller infiltration systems (trenches or drywells) may be applicable if local soil conditions allow. See sections I-01 and I-03 for more information. Avoid steep slopes or other geologic conditions that could potentially be made unstable by infiltrating water into the ground.

Natural Depressions, Sinkholes, and Karst Topography

Much bedrock in Tennessee is composed of fractured limestone formations that are likely to contain unusual strike angles and/or nonconformities. Karst topography is defined as the presence of limestone or other soluble geology that is likely to form caverns, sinkholes, or other dissolved formations. A sinkhole is a surface depression, typically linked to an underground cavern system, which occurs primarily in limestone regions. See Figure I-02-3 for a typical sketch of a sinkhole.

For natural depressions and sinkholes, it is generally required that the postdeveloped peak flows and total stormwater runoff volume must be limited to the predeveloped values. In addition, it may be required that no structures will be flooded from a 100-year storm assuming plugged conditions (zero outflow). It is greatly desired that runoff should be treated using one or more stormwater treatment BMPs, prior to discharging toward a sinkhole or other natural depression.

Consideration may be given to recommendations that are based upon advanced subsurface testing or visual inspection by experts or professional engineers with demonstrated experience in hydrogeology. Tennessee Department of Environment and Conservation (TDEC) requires anyone who performs a dye trace study to obtain a TDEC registration for this activity (see TDEC website). Major sinkholes are considered to be waters of the state; filling or otherwise altering a large sinkhole requires an Aquatic Resources Alteration Permit from TDEC.

Construction/ Inspection Considerations

- It is very important to protect the natural infiltration rate by using light equipment and construction procedures that minimize compaction. Stormwater must be allowed to enter the facility until all construction in the catchment area is completed and the work area is stabilized. If this prohibition is not feasible in particular situations, do not excavate the facility to final grade until after all construction is complete upstream.
- Protect infiltration surface during construction.
- Geotextile fabric should be selected on the basis of durability, with an adequate opening size to resist clogging.
- Use clean washed aggregate (little or no fines).
- If the bottom of the basin has been compacted due to construction vehicles or other means, it should be rototilled to replenish its infiltration capacity.
- Protect the area from heavy equipment and traffic by physical means.
- Improperly functioning infiltration basins must be replaced by other stormwater treatment BMPs that are capable of providing water quality treatment.

Maintenance

- Inspect and observe the infiltration system several times during the first year, particularly after heavy rainfall events. Use observation wells and cleanout ports to monitor water levels and drawdown times. Record all observations and measurements taken. Perform any maintenance and repairs promptly.
- Inspect the infiltration system annually thereafter, and after extreme rainfall events. If stormwater does not infiltrate within 48 hours after a storm, it is generally time to clean, repair or replace the facility. Remove debris and sediment at least annually to avoid high concentrations of pollutants and loss of infiltration capacity.
- The primary objective of maintenance and inspection activities is to ensure that the infiltration facility continues to perform as designed. Regular inspection can substantially lengthen the required time interval between major rehabilitations.
- Prevent compaction of the infiltration surfaces by physical controls such as gates or fences. Maintain dense grass vegetation for infiltration basins. Use rotary tillers on infiltration surfaces when needed to restore infiltration capacity and to control weed growth.

- Maintenance considerations should include the possibility of replacing an infiltration basin every 5 years, as the gravel and geotextile fabric will eventually become clogged and cease to function. Clogging may also occur at the bottom of the basin, along the gravel / soil interface. Clogging will occur even faster if there are fine silts, oil and grease, fertilizers and other materials present in stormwater runoff. Do not allow trees or other woody vegetation to become rooted along an infiltration basin. Inspect operation and recovery of infiltration trench at least a few times a year.
- Pretreatment of stormwater runoff may reduce maintenance costs by capturing coarse sediments and floatable materials in a smaller structure that can be more easily cleaned. All infiltration trenches should be inspected several times the first year and at least twice a year thereafter.
- Rake the bottom of the infiltration basin at regular intervals, to prevent clogging.
- Maintain records of inspections and maintenance performed.

Sediment Removal

A primary function of stormwater treatment BMPs is to collect and remove sediments. The sediment accumulation rate is dependent on a number of factors including watershed size, facility sizing, construction upstream, nearby industrial or commercial activities, etc. Sediments should be identified before sediment removal and disposal is performed. Special attention or sampling should be given to sediments accumulated from industrial or manufacturing facilities, heavy commercial sites, fueling centers or automotive maintenance areas, parking areas, or other areas where pollutants are suspected. Treat sediment as potentially hazardous soil until proven otherwise.

Some sediment may contain contaminants for which TDEC requires special disposal procedures. Consult TDEC – Division of Water Pollution Control if there is any uncertainty about what the sediment contains or if it is known to contain contaminants. Clean sediment may be used as fill material, hole filling, or land spreading. It is important that this material not be placed in a way that will promote or allow resuspension in stormwater runoff. Some demolition or sanitary landfill operators will allow the sediment to be disposed at their facility for use as cover. This generally requires that the sediment be tested to ensure that it is innocuous.

Cost Considerations

Construction costs include clearing, grading, excavation, placement of the filter fabric, placement of the stone aggregate, installation of the monitoring well, and establishment of a vegetated buffer strip. Infiltration basin construction costs are estimated to be ten to twenty percent higher than conventional dry ponds (Schueler, et al, 1992).

Pretreatment will reduce maintenance costs by capturing gross settleable solids and floatables in a smaller space that can be more easily cleaned. Maintenance activities include inspection, maintaining the pretreatment facility, mowing, buffer maintenance, tree pruning or removal, sediment removal, and eventual rehabilitation. The costs of these activities vary from place to place.

Limitations

- The four major concerns with infiltration basins are clogging, potential impact

on other structures and properties, accumulation of heavy metals, and the potential for groundwater contamination.

- Clogging and high maintenance costs are very likely to occur in fine soils that are marginally allowable for infiltration rates. Erosion control is extremely important to prevent clogging; infiltration basins fail if they receive high sediment loads. Perform regular maintenance and inspections to minimize the potential for clogging and loss of infiltration capacity. Pretreatment is highly recommended for stormwater runoff from many land uses, prior to discharging to an infiltration basin.
- Infiltration basins are not appropriate for areas with high groundwater tables, steep slopes, lots of underground infrastructure, and nearby buildings.
- Infiltration basins tend to fail very easily and have short life spans. This is due to premature clogging of the facility, low permeable soils, and high water table.
- There are many restrictions on the use of infiltration basins, including soil type, depth to water table and bedrock, slopes, and contributing watershed area. Careful investigations of these conditions must be performed to determine if an infiltration trench is best suited to the location over another BMP.
- Heavy metals are likely to settle in infiltration basins. High levels of heavy metals have been observed in other states where adequate maintenance was not performed. Toxic levels are not likely to be exceeded, but the sediments will need to be handled as hazardous waste after a few years of neglect.
- There is a higher risk of groundwater contamination in very coarse soils. It is highly recommended that a monitoring and inspection program should be used to verify that no contamination occurs. Infiltration basins may not be appropriate where there is significant potential for hazardous chemical spills or near drinking water wells.
- Constructing an infiltration basin over compacted fill soils should be avoided because they greatly reduce the exfiltration capacity of the basin.
- The use of infiltration basins is very limited in ultra-urban areas because of unsuitable soils and space considerations.
- Infiltration trenches are generally suitable only for small sites of a few acres.

Additional Information

- Infiltration trenches or wet detention should be considered where dissolved pollutants discharging to surface waters are of concern. However, satisfactory removal efficiencies require soils that contain loam. Coarse soils are not effective at removing dissolved pollutants and fine particulates before the stormwater reaches the ground water aquifer.
- Problems can be expected with infiltration trenches placed in finer soils. The State of Maryland has emphasized these systems for about 10 years where they have been installed in soils with infiltration rates as low as 0.27 inches (0.69 cm) per hour. A recent survey (Lindsey, et al., 1991) found that a third of the facilities examined

(177) were clogged and another 18% were experiencing slow infiltration.

- Based on a review of several studies of infiltration facilities in sandy and loamy soils, it has been concluded that "monitoring . . . has not demonstrated significant contamination . . . although highly soluble pollutants such as nitrate and chloride have been shown to migrate to ground water" (USEPA, 1991). However, pollution has been found in ground water where infiltration devices are in coarse gravels (Adophson, 1989; Miller, 1987).

- Clogging has not been a problem with well maintained systems discharging to sands and coarser soils, suggesting that pretreatment for these infiltration devices in the aforementioned soil conditions is not necessary. Pretreatment when infiltrating to finer soils is suggested. An infiltration facility sized only for treatment is much smaller than one sized for flood control and therefore may be more susceptible to clogging.

- For small systems treating less than a few acres of pavement, pretreatment can be accomplished with a stormwater quality inlet, catch basin and a submerged outlet. The diameter and depth of the sump should be at least four times the diameter of the outlet pipe to the infiltration system (Lager, et al., 1977). Swales can also be used although they will not likely be feasible in industrial sites that tend to be fully utilized.

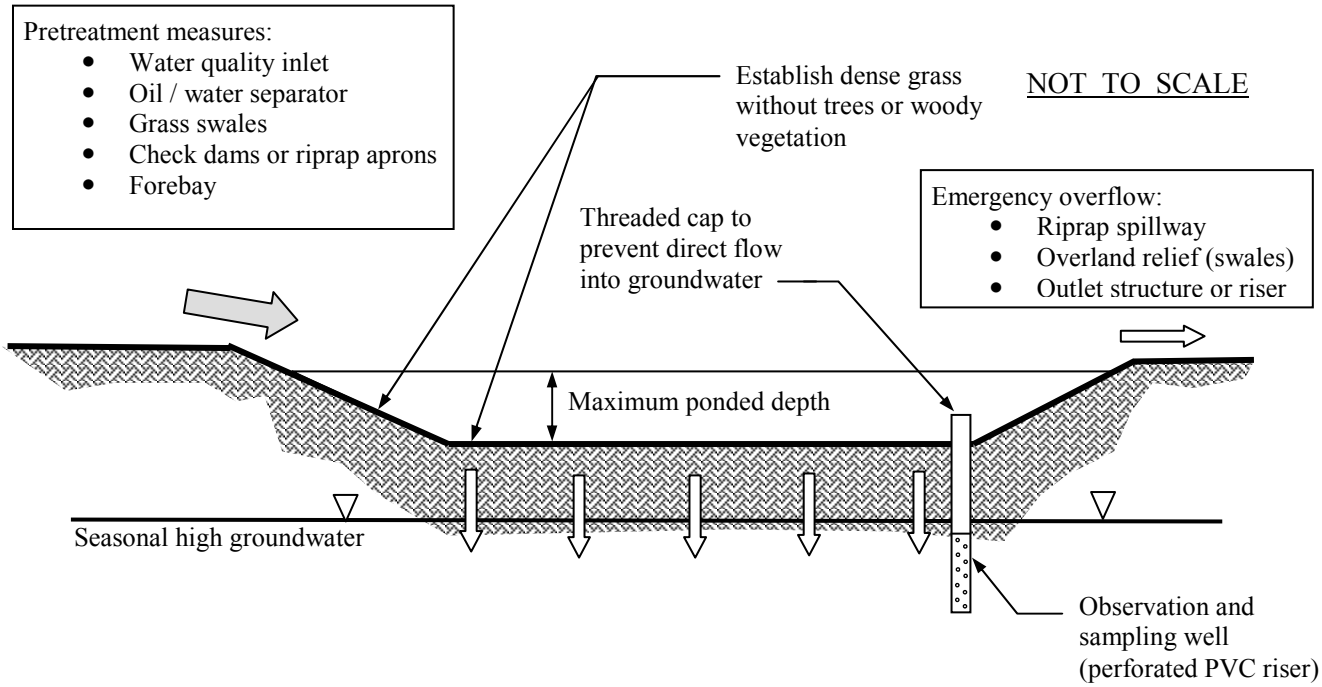


Figure I-02-2
Typical Infiltration Basin

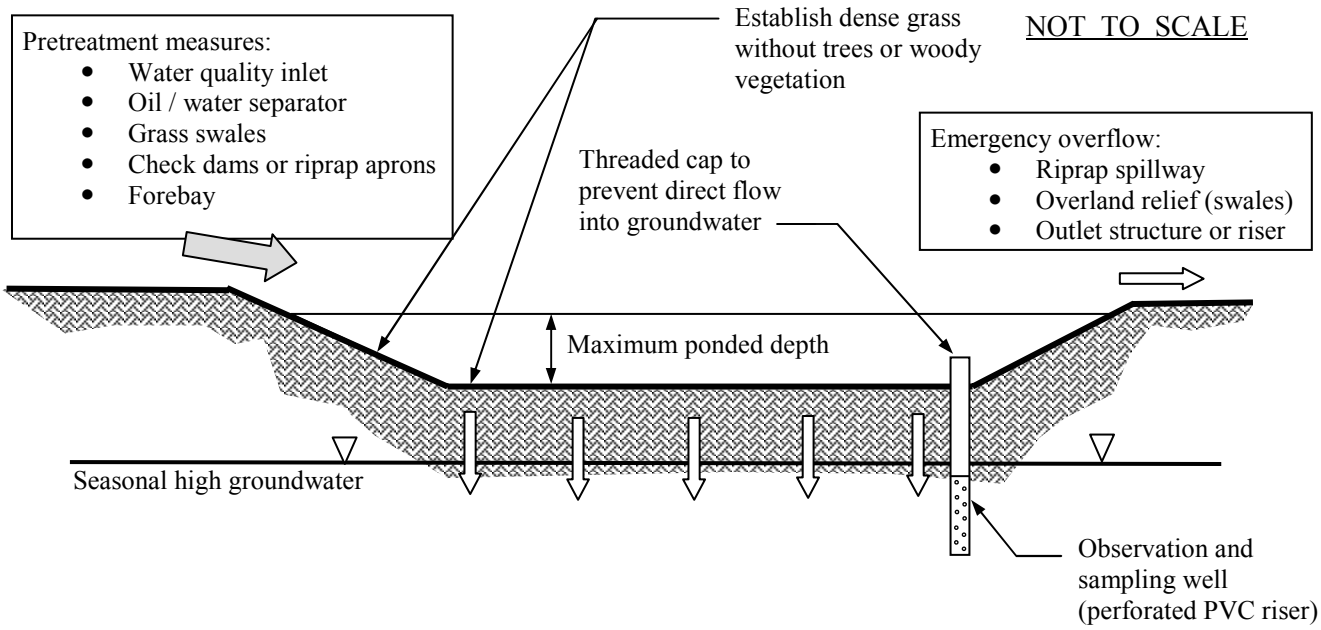
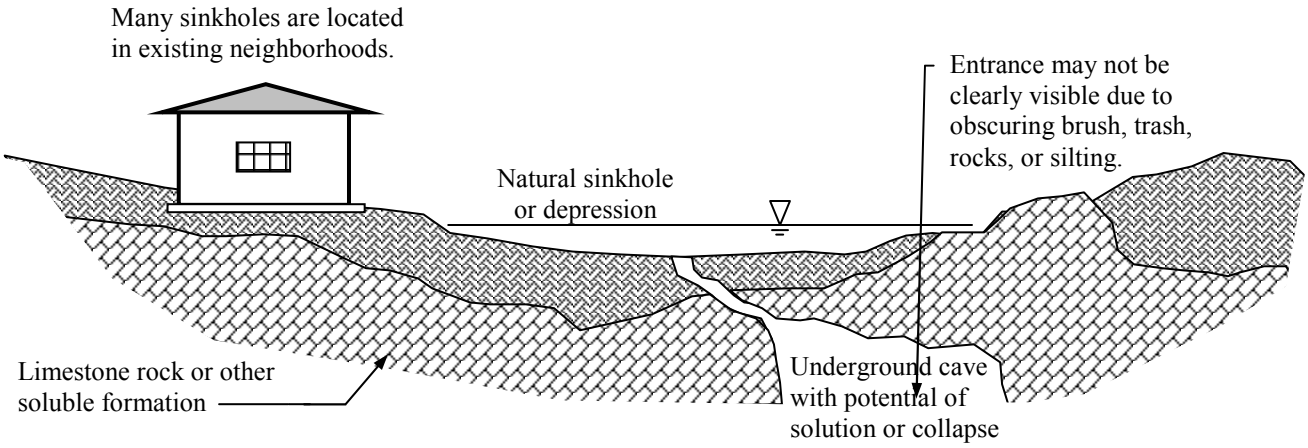


Figure I-02-2
Typical Infiltration Basin



Increasing stormwater runoff to a natural depression may increase sinkhole formation by further dissolving limestone. Even if amount of stormwater runoff has not been increased, stormwater quality treatment is necessary to prevent pollutants from entering groundwater and to reduce potential pH changes and chemicals within stormwater runoff.

NOT TO SCALE

Figure I-02-3
Typical Schematic of Sinkholes and Karst Areas

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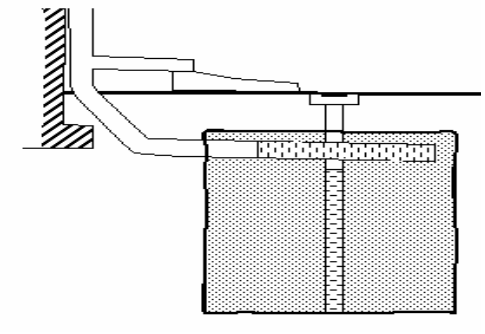
ACTIVITY: Underground Drainage Systems

I – 03



Targeted Constituents				
● Significant Benefit		◗ Partial Benefit		○ Low or Unknown Benefit
● Sediment	◗ Heavy Metals	◗ Floatable Materials	◗ Oxygen Demanding Substances	
◗ Nutrients	◗ Toxic Materials	◗ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes
Implementation Requirements				
● High		◗ Medium	○ Low	
◗ Capital Costs	◗ O & M Costs	● Maintenance	○ Training	

Description

This BMP covers subsurface infiltration BMPs such as drywells and vaults. Infiltration rates in much of the state are typically poor due to clay soils and bedrock. Such locations may not be suitable of infiltration BMPs. Infiltration systems work best at sites having sandy loam types of soils. Areas containing karst topography and sinkholes may initially appear to have excellent infiltration, but should be considered as unreliable and will require very careful investigation and analysis.

Selection Criteria

- Underground drainage systems, such as drywells and vaults are suitable for draining small impervious surfaces, such as parking lots or residential rooftops, for which the adjacent pervious area has soils with adequate infiltration rates.
- Natural sinkholes (or other evidences of karst topography and drainage) are not considered to be infiltration systems for use in treating stormwater quality or in providing stormwater detention. In general, stormwater drainage may continue to flow to a natural sinkhole at a rate that is representative of natural undeveloped conditions. No unusual or unfavorable geologic conditions shall be present near the sinkhole that indicates subsidence, piping, increased limestone dissolution, potential collapse or other safety concerns.

Design and Sizing Considerations

Infiltration can be a very desirable method of stormwater treatment for land uses which do not heavily pollute stormwater runoff. For instance, established residential areas typically have less pollution than industrial and commercial areas. The primary physical conditions necessary for infiltration are: 1) permeable soils which have not been compacted or graded, and 2) low and non-interfering groundwater tables. Stormwater runoff from parking lots or buildings should be pretreated with a water quality enhancing inlet, oil/water separator, grass swale or other type of stormwater treatment BMPs. Small amounts of stormwater runoff from selected impervious areas are given an opportunity to infiltrate. A factor of safety should be incorporated into the design to ensure that the system still works even when partially clogged.

The recommended minimum infiltration rate is at least 0.5 inches per hour, but may depend on type of infiltration system and the desired water quality treatment involved. Drawdown should occur within 48 hours. An infiltration basin or trench must have at

least 3 feet separation from seasonal high groundwater and at least 4 feet separation from bedrock. Coarse soils are not as effective in filtering groundwater; therefore provide at least 6 to 8 feet separation from seasonal high groundwater for sand and gravel soils.

Unless adequate engineering documentation is submitted, an infiltration system must be located at least 100 feet away from any drinking water well, septic tank or drainfield. It is also recommended that an infiltration trench should not be located near building foundations, buildings with basements or crawl spaces, major roadways, wetlands, streams, or potentially unstable slopes and hillsides.

Overview of Infiltration Theory

The overall degree of water quality treatment achieved by infiltration is a function of the amount of stormwater that is captured and infiltrated over time. Minimum infiltration storage is generally required to be the first flush volume.

Typical infiltration rates are shown in Table I-03-1. The USDA soil texture classification is based upon the triangle shown in Figure I-03-1, with the following definitions:

	Approximate size	Rough description
Gravel	> 2 mm	> No. 8 sieve or so
Sand	0.05 mm to 2 mm	> No. 200 sieve
Silt	0.002 mm to 0.05 mm	Little plasticity or cohesion
Clay	< 0.002 mm	Can be rolled and compressed

For preliminary design, infiltration rates may be estimated using a published soil survey. However, final design must include soil gradation testing and measurement of unsaturated vertical infiltration rates in the field by the double-ring infiltrometer test. This test is not appropriate for clay soils or other soils which clearly appear to be unsuitable for infiltration methods. The allowable infiltration rate is 0.5 inches per hour, although an infiltration rate of 1 inch per hour is highly recommended. Table I-03-1 shows that soils with a hydrologic soil group of C or D will not have sufficient infiltration rates.

Another well-known method of categorizing soils and evaluating soil properties is by the Unified Soil Classification System (USCS). The following soil groups are generally acceptable as good soils for infiltration:

SW	Well-graded sands and gravelly sands, little or no fines
SP	Poorly graded sands and gravelly sands, little or no fines
SM	Silty sands, sand-silt mixtures

Table I-03-1
Typical Infiltration Rates from USDA Soil Texture

	USDA Soil Texture	Typical Water Capacity (inches per inch of soil)	Typical Infiltration Rate (inches per hour)	Hydrologic Soil Group
*	Sand	0.35	8.27	A
**	Loamy sand	0.31	2.41	A
**	Sandy loam	0.25	1.02	B
**	Loam	0.19	0.52	B
	Silt loam	0.17	0.27	C
	Sandy clay loam	0.14	0.17	C
	Clay loam	0.14	0.09	D
	Silty clay loam	0.11	0.06	D
	Sandy clay	0.09	0.05	D
	Silty clay	0.09	0.04	D
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* - Suitable for infiltration with typical 6' to 8' separation from seasonal high groundwater
** - Suitable for infiltration with at least 3' separation from seasonal high groundwater

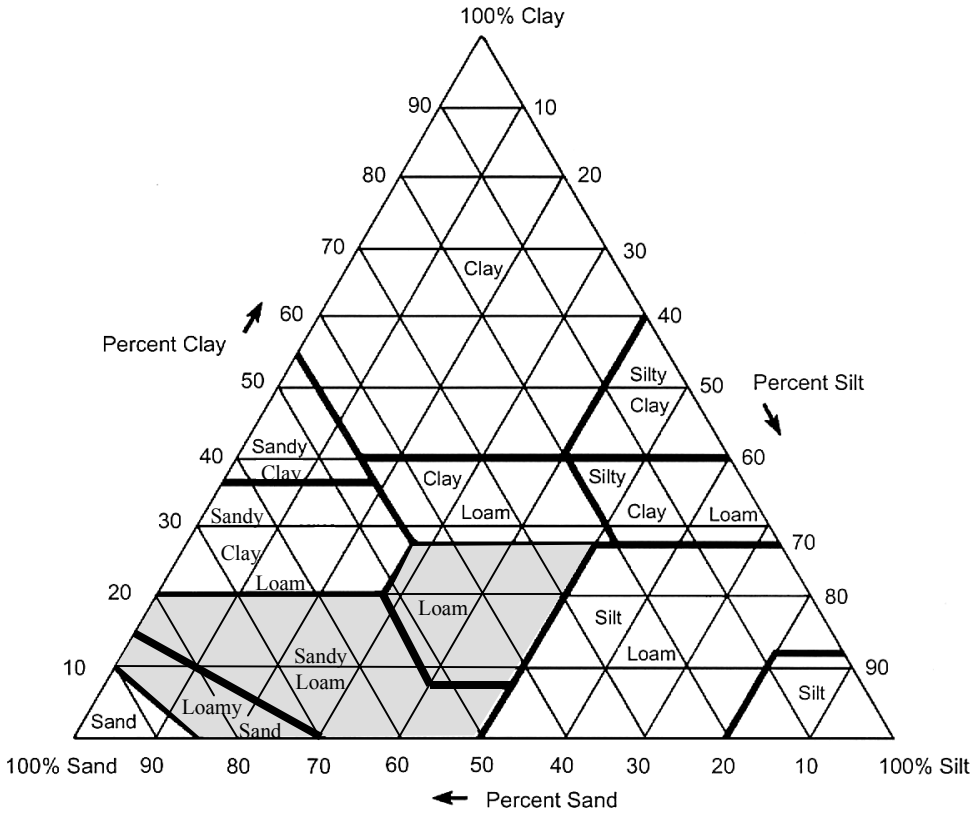


Figure I-03-1
USDA Soils Triangle

Natural Depressions, Sinkholes, and Karst Topography

Much bedrock in Tennessee is composed of fractured limestone formations that are likely to contain unusual strike angles and/or nonconformities. Karst topography is defined as the presence of limestone or other soluble geology that is likely to form caverns, sinkholes, or other dissolved formations. A sinkhole is a surface depression, typically linked to an underground cavern system, which occurs primarily in limestone regions. See Figure I-03-3 for a typical sketch of a sinkhole.

For natural depressions and sinkholes, it is generally required that the post-developed peak flows and total stormwater runoff volume must be limited to the pre-developed values. In addition, it may be required that no structures will be flooded from a 100-year storm assuming plugged conditions (zero outflow). It is greatly desired that runoff should be treated using one or more stormwater treatment BMPs, prior to discharging toward a sinkhole or other natural depression.

Consideration may be given to recommendations that are based upon advanced subsurface testing or visual inspection by experts or professional engineers with demonstrated experience in hydrogeology. Tennessee Department of Environment and Conservation (TDEC) requires anyone who performs a dye trace study to obtain a TDEC registration for this activity (see TDEC website). Major sinkholes are considered to be waters of the state; filling or otherwise altering a large sinkhole requires an Aquatic Resources Alteration Permit from TDEC.

A drywell or dry vault can be used to infiltrate stormwater runoff from small areas of impervious runoff, such as roofs or parking lots. The designer should be very careful to avoid adverse impacts to foundations, basements, unstable slopes or hillsides, septic tanks, utility lines, etc. A small pretreatment chamber with a screen is recommended in many instances to handle leaves (roofs) or trash and sediment (parking lots).

A typical drywell adjacent to a house foundation is shown in Figure I-03-2 (without a pretreatment chamber). A dry vault (larger than a drywell) can be constructed using masonry blocks and a poured concrete lid to hold a larger volume of stormwater runoff. Inspect the drywell or dry vault on a regular basis.

Construction/ Inspection Considerations

- It is very important to protect the natural infiltration rate by using light equipment and construction procedures that minimize compaction. Stormwater must be allowed to enter the facility until all construction in the catchment area is completed and the work area is stabilized. If this prohibition is not feasible in particular situations, do not excavate the facility to final grade until after all construction is complete upstream.
- Protect infiltration surface during construction.
- Inspect frequently for clogging during construction.
- Improperly functioning infiltration systems must be replaced by other stormwater treatment BMPs that are capable of providing water quality treatment.

Maintenance

- Maintenance can be difficult and costly for infiltration systems, with a potential for high maintenance costs due to clogging. Maintenance costs and site access should be carefully considered prior to design.

- Pretreatment of stormwater runoff may reduce maintenance costs by capturing coarse sediments and floatable materials in a smaller structure that can be more easily cleaned.

- Inspect and observe the infiltration system several times during the first year, particularly after heavy rainfall events. Use observation wells and cleanout ports to monitor water levels and drawdown times. Record all observations and measurements taken. Perform any maintenance and repairs promptly.

- Inspect the infiltration system annually thereafter, and after extreme rainfall events. If stormwater does not infiltrate within 48 hours after a storm, it is generally time to clean, repair or replace the facility. Remove debris and sediment at least annually to avoid high concentrations of pollutants and loss of infiltration capacity.

- The primary objective of maintenance and inspection activities is to ensure that the infiltration facility continues to perform as designed. Regular inspection can substantially lengthen the required time interval between major rehabilitations.

- Prevent compaction of the infiltration surfaces by physical controls such as gates or fences. Maintain dense grass vegetation for infiltration basins. Use rotary tillers on infiltration surfaces when needed to restore infiltration capacity and to control weed growth.

- Maintenance plans should include provisions to repair or replace this type of structure after 5 years or so.

- Maintain records of inspections and maintenance performed.

Sediment Removal

A primary function of stormwater treatment BMPs is to collect and remove sediments. The sediment accumulation rate is dependent on a number of factors including watershed size, facility sizing, construction upstream, nearby industrial or commercial activities, etc. Sediments should be identified before sediment removal and disposal is performed. Special attention or sampling should be given to sediments accumulated from industrial or manufacturing facilities, heavy commercial sites, fueling centers or automotive maintenance areas, parking areas, or other areas where pollutants are suspected. Treat sediment as potentially hazardous soil until proven otherwise.

Some sediment may contain contaminants for which TDEC requires special disposal procedures. Consult TDEC – Division of Water Pollution Control if there is any uncertainty about what the sediment contains or if it is known to contain contaminants. Clean sediment may be used as fill material, hole filling, or land spreading. It is important that this material not be placed in a way that will promote or allow resuspension in stormwater runoff. Some demolition or sanitary landfill operators will allow the sediment to be disposed at their facility for use as cover. This generally requires that the sediment be tested to ensure that it is innocuous.

Cost Considerations

- Maintenance is difficult and costly for underground trenches.
- Potential for high maintenance costs due to clogging.
- Pretreatment will reduce maintenance costs by capturing gross settleable solids and floatables in a smaller space that can be more easily cleaned.

Limitations

- The four major concerns with infiltration systems are clogging, potential impact on other structures and properties, accumulation of heavy metals, and the potential for groundwater contamination.
- Clogging and high maintenance costs are very likely to occur in fine soils that are marginally allowable for infiltration rates. Erosion control is extremely important to prevent clogging; infiltration systems fail if they receive high sediment loads. Perform regular maintenance and inspections to minimize the potential for clogging and loss of infiltration capacity. Pretreatment is highly recommended for stormwater runoff from many land uses, prior to discharging to an infiltration system.
- Infiltration systems are not appropriate for areas with high groundwater tables, steep slopes, lots of underground infrastructure, and nearby buildings.
- Heavy metals are likely to settle in any of the stormwater treatment BMPs, but particularly for infiltration systems (which have the lowest velocity). High levels of heavy metals have been observed in other states where adequate maintenance was not performed. Toxic levels are not likely to be exceeded, but the sediments will need to be handled as hazardous waste after a few years of neglect.
- There is a higher risk of groundwater contamination in very coarse soils. It is highly recommended that a monitoring and inspection program should be used to verify that no contamination occurs. Infiltration systems may not be appropriate where there is significant potential for hazardous chemical spills, or near drinking water wells.

Additional Information

- Underground drainage systems are suitable only for small sites of a few acres.
- Infiltration systems or wet detention should be considered where dissolved pollutants discharging to surface waters are of concern. However, satisfactory removal efficiencies require soils that contain loam. Coarse soils are not effective at removing dissolved pollutants and fine particulates before the stormwater reaches the ground water aquifer.
- Problems can be expected with infiltration systems placed in finer soils. The State of Maryland has emphasized these systems for about 10 years where they have been installed in soils with infiltration rates as low as 0.27 inches (0.69 cm) per hour. A recent survey (Lindsey, et al., 1991) found that a third of the facilities examined (177) were clogged and another 18% were experiencing slow infiltration. Dry wells that treat roof runoff had the fewest failures (4%) and porous pavement the most (77%). Dry wells may have the lowest failure rate because they only handle roof runoff. The primary causes of failure appear to be inadequate pretreatment and lack of soil stabilization in the tributary watershed, as well as poor construction practices (Shaver, personal communication).

- Based on a review of several studies of infiltration facilities in sandy and loamy soils, it has been concluded that "monitoring . . . has not demonstrated significant contamination . . . although highly soluble pollutants such as nitrate and chloride have been shown to migrate to ground water" (USEPA, 1991). However, pollution has been found in ground water where infiltration devices are in coarse gravels (Adophson, 1989; Miller, 1987).
- Clogging has not been a problem with well maintained systems discharging to sands and coarser soils, suggesting that pretreatment for these infiltration devices in the aforementioned soil conditions is not necessary. Pretreatment when infiltrating to finer soils is suggested. An infiltration facility sized only for treatment is much smaller than one sized for flood control and therefore may be more susceptible to clogging.
- For small systems treating less than a few acres of pavement, pretreatment can be accomplished with a stormwater quality inlet, catch basin and a submerged outlet. The diameter and depth of the sump should be at least four times the diameter of the outlet pipe to the infiltration system (Lager, et al., 1977). Swales can also be used although they will not likely be feasible in industrial sites that tend to be fully utilized.
- Pretreatment of the stormwater is highly recommended for drywells where access for maintenance is difficult if not impossible. Such pretreatment may include biofilters, sumps, stormwater quality enhancing inlets, or oil water separators.

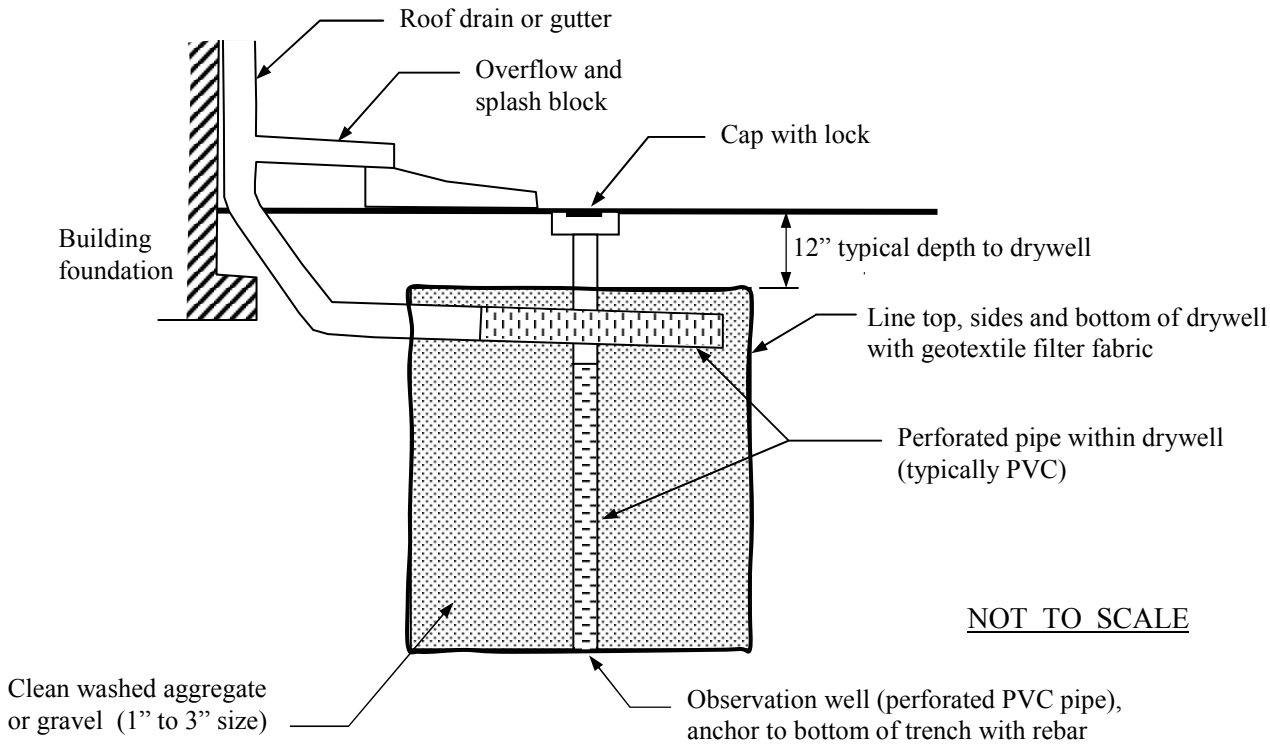
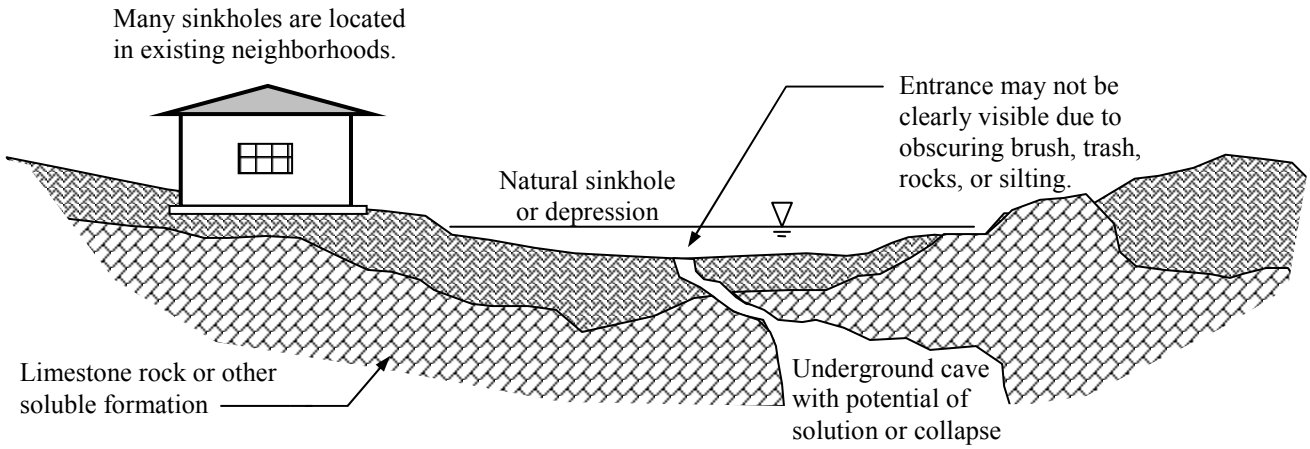


Figure I-03-2
Typical Drywell (With Rooftop Drainage)



Increasing stormwater runoff to a natural depression may increase sinkhole formation by further dissolving limestone. Even if amount of stormwater runoff has not been increased, stormwater quality treatment is necessary to prevent pollutants from entering groundwater and to reduce potential pH changes and chemicals within stormwater runoff.

NOT TO SCALE

Figure I-03-3
Typical Schematic of Sinkholes and Karst Areas

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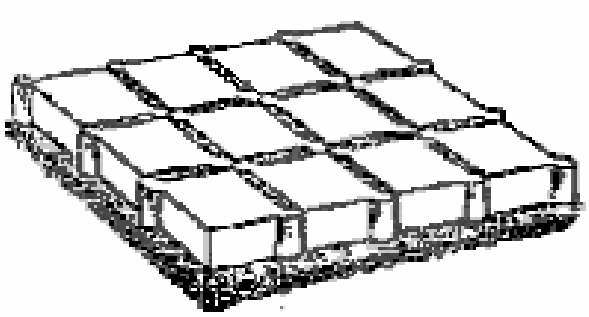
ACTIVITY: Porous Pavement

I – 04



Targeted Constituents				
● Significant Benefit		◗ Partial Benefit	○ Low or Unknown Benefit	
● Sediment	◗ Heavy Metals	◗ Floatable Materials	◗ Oxygen Demanding Substances	
◗ Nutrients	◗ Toxic Materials	◗ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes
Implementation Requirements				
● High		◗ Medium	○ Low	
◗ Capital Costs	◗ O & M Costs	◗ Maintenance	○ Training	

Description

This BMP covers porous pavement systems for increasing infiltration and decreasing surface runoff volume. Porous pavement is a specially designed pavement which allows stormwater to pass through it. It is effective in reducing flood peak flows and does so by allowing stormwater to infiltrate through a porous upper asphalt layer and into a stone aggregate reservoir below. Runoff eventually infiltrates into the ground or may be directed through an underdrain collection system.

There are three main types of porous pavement: poured asphalt pavement, poured concrete pavement, and interlocking-grid. The first two are special mixes of asphalt and concrete pavement, while the last type is a network of blocks (usually concrete) used to decrease impervious area.

Infiltration rates in much of the state are typically poor due to clay soils and bedrock. Such locations may not be suitable of infiltration BMPs. Infiltration systems work best at sites having sandy loam types of soils. Areas containing karst topography and sinkholes may initially appear to have excellent infiltration, but should be considered as unreliable and will require very careful investigation and analysis.

Selection Criteria

- Porous pavements make a generally impervious surface into a semi-pervious surface, and do not usually function as a true infiltration system. There is a basic conflict for non-sandy soils to both support vehicle loads and allow water to infiltrate. Porous pavements should be restricted to light traffic conditions without heavy truck use, such as residential driveways and overflow parking lots. In addition, porous pavements can receive runoff from adjacent paved areas or rooftop storage.

- Porous pavement has the capability to remove both soluble and fine particulate pollutants in urban runoff, enhance groundwater recharge, control streambank erosion, and increase low flow.

- It has been shown to have high removal rates for sediment, nutrients, organic matter, and trace metals.

- Adsorption, trapping/straining in the void spaces between soil particles, and reducing organic matter by aerobic bacteria within the soil are a few of the pollutant removal mechanisms of porous pavement.
- Natural sinkholes (or other evidences of karst topography and drainage) are not considered to be suitable locations for infiltration systems for use in treating stormwater quality or in providing stormwater detention. In general, stormwater drainage may continue to flow to a natural sinkhole at a rate that is representative of natural undeveloped conditions. No unusual or unfavorable geologic conditions shall be present near the sinkhole that indicates subsidence, piping, increased limestone dissolution, potential collapse or other safety concerns.
- The use of porous pavement requires deep, permeable soils, low-density traffic, and suitable adjacent land uses.

Design and Sizing Considerations

Infiltration can be a very desirable method of stormwater treatment for land uses which do not heavily pollute stormwater runoff. For instance, established residential areas typically have less pollution than industrial and commercial areas. The primary physical conditions necessary for infiltration are: 1) permeable soils which have not been compacted or graded, and 2) low and non-interfering groundwater tables. Stormwater runoff from parking lots or buildings should be pretreated with a water quality enhancing inlet, oil/water separator, grass swale or other type of stormwater treatment BMPs. Small amounts of stormwater runoff from selected impervious areas are given an opportunity to infiltrate.

Inspect frequently for clogged soils and for ineffective infiltration rates. Improperly functioning infiltration systems must be replaced by other stormwater treatment BMPs that are capable of providing water quality treatment.

The recommended minimum infiltration rate is at least 0.5 inches per hour, but may depend on type of infiltration system and the desired water quality treatment involved.

Due to its complexity, the design of porous pavement should only be completed by a licensed professional engineer who is trained and experienced in porous pavement design and construction.

Following are some design criteria for porous pavement:

- Maximum drainage time of two days to allow for drying of the underlying soils and to maintain aerobic conditions; also allowing the reservoir to empty for the next storm.
- Highly permeable soils to allow for maximum infiltration.
- Clean-washed aggregate to prevent clogging from pre-existing sediment.
- Organic matter in the subsoils.
- Pretreatment of off-site runoff to reduce the pollutant load onto the pavement.
- Heavy trucks and equipment should be diverted from areas with porous pavement.
- Slopes underlying porous pavement should be as flat as possible, with maximum

grades being less than five percent.

- There should be a minimum of three feet clearance between the bottom of the stone reservoir and the bedrock level.
- A minimum of two to four feet between the stone reservoir level and the seasonally high water table is needed.
- The standard porous pavement design should withstand normal freeze/thaw conditions. However, it is very susceptible to clogging during snow removal operations such as sand and salt application
- Most soils in urbanized areas are not capable of providing adequate infiltration rates because of compaction or other prior modifications. Therefore, retrofitting is extremely limited.
- Porous pavement should be designed to exfiltrate a minimum runoff volume equal to the first one-half inch of runoff from impervious areas that contribute to the site.
- To ensure that proper pollutant removal occurs, the minimum drainage time for the stone reservoir should be 12 hours; and the maximum drainage time should be 48 hours to ensure that the stone reservoir is completely drained before the next storm event. This maximizes pollutant removal and readies the pond for the next storm.
- To remove oil, dirt, and grit from off-site facilities, a pre-treatment facility such as a sand filter or water quality inlet should be installed to prevent the sediments from entering the stone reservoir.
- Different design options can prolong the life of the porous pavement system. One idea brought forth in the *Virginia Stormwater Management Handbook* is to "daylight" the aggregate base along the downslope edge of the pavement, forming a chimney drain into the stone storage reservoir beneath the pavement. If the pavement clogs, the runoff can flow into the stone reservoir.

Overview of Infiltration Theory

The overall degree of water quality treatment achieved by infiltration is a function of the amount of stormwater that is captured and infiltrated over time.

Typical infiltration rates are shown in Table I-04-1. The USDA soil texture classification is based upon the soils triangle shown in Figure I-04-1, with the following definitions:

	Approximate size	Rough description
Gravel	> 2 mm	> No. 8 sieve or so
Sand	0.05 mm to 2 mm	> No. 200 sieve
Silt	0.002 mm to 0.05 mm	Little plasticity or cohesion
Clay	< 0.002 mm	Can be rolled and compressed

For preliminary design, infiltration rates may be estimated using a published soil survey. However, final design must include soil gradation testing and measurement of unsaturated vertical infiltration rates in the field by the double-ring infiltrometer test. This test is not appropriate for clay soils or other soils which clearly appear to be unsuitable for infiltration methods. The allowable infiltration rate is 0.5 inches per hour, although an infiltration rate of 1 inch per hour is highly recommended. Table I-04-1 shows that soils with a hydrologic soil group of C or D will not have sufficient infiltration rates.

Another well-known method of categorizing soils and evaluating soil properties is by the Unified Soil Classification System (USCS). The following soil groups are generally acceptable as good soils for infiltration:

SW	Well-graded sands and gravelly sands, little or no fines
SP	Poorly graded sands and gravelly sands, little or no fines
SM	Silty sands, sand-silt mixtures

Table I-04-1
Typical infiltration Rates from USDA Soil Texture

	USDA Soil Texture	Typical Water Capacity (inches per inch of soil)	Typical Infiltration Rate (inches per hour)	Hydrologic Soil Group
*	Sand	0.35	8.27	A
**	Loamy sand	0.31	2.41	A
**	Sandy loam	0.25	1.02	B
**	Loam	0.19	0.52	B
	Silt loam	0.17	0.27	C
	Sandy clay loam	0.14	0.17	C
	Clay loam	0.14	0.09	D
	Silty clay loam	0.11	0.06	D
	Sandy clay	0.09	0.05	D
	Silty clay	0.09	0.04	D
	Clay	0.08	0.02	D

* - Suitable for infiltration with typical 6’ to 8’ separation from seasonal high groundwater
** - Suitable for infiltration with at least 3’ separation from seasonal high groundwater

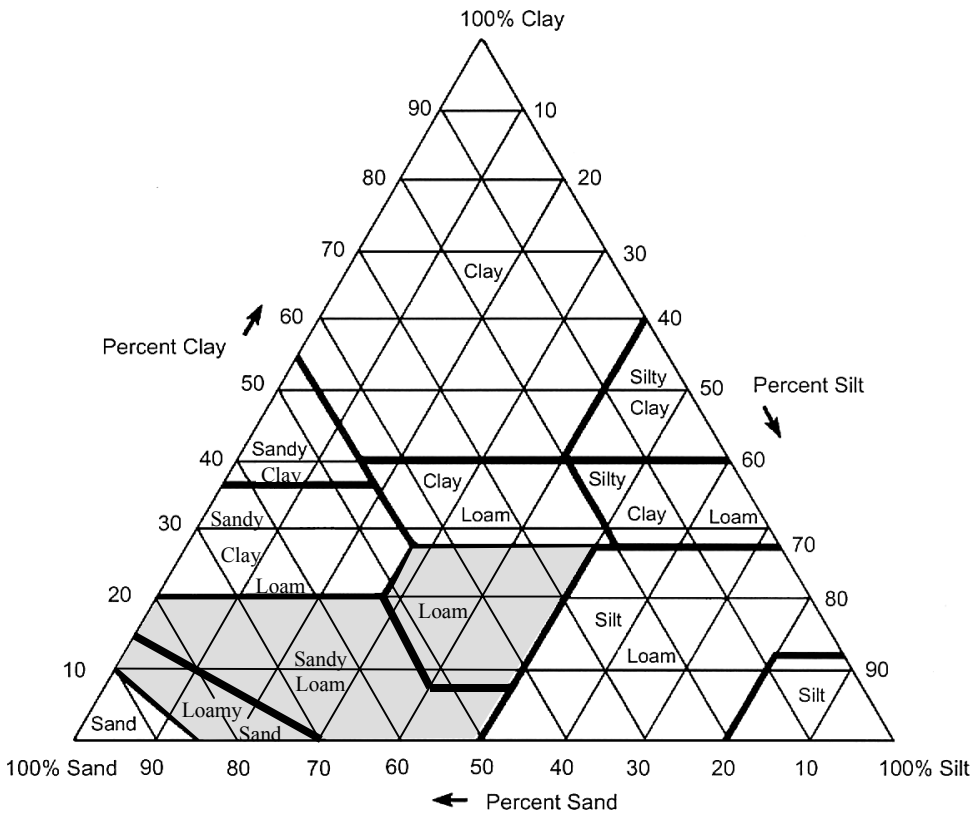


Figure I-04-1
USDA Soils Triangle

Natural Depressions, Sinkholes, and Karst Topography

Much bedrock in Tennessee is composed of fractured limestone formations that are likely to contain unusual strike angles and/or nonconformities. Karst topography is defined as the presence of limestone or other soluble geology that is likely to form caverns, sinkholes, or other dissolved formations. A sinkhole is a surface depression, typically linked to an underground cavern system, which occurs primarily in limestone regions. See Figure I-03-3 for a typical sketch of a sinkhole.

For natural depressions and sinkholes, it is generally required that the post-developed peak flows and total stormwater runoff volume must be limited to the pre-developed values. In addition, it may be required that no structures will be flooded from a 100-year storm assuming plugged conditions (zero outflow). It is greatly desired that runoff should be treated using one or more stormwater treatment BMPs, prior to discharging toward a sinkhole or other natural depression.

Consideration may be given to recommendations that are based upon advanced subsurface testing or visual inspection by experts or professional engineers with demonstrated experience in hydrogeology. Tennessee Department of Environment and Conservation (TDEC) requires anyone who performs a dye trace study to obtain a TDEC registration for this activity (see TDEC website). Major sinkholes are considered to be waters of the state; filling or otherwise altering a large sinkhole requires an Aquatic Resources Alteration Permit from TDEC.

Porous Pavement

Porous pavements are not actually considered as a true infiltration system unless there is a mechanism for ensuring that captured water is vertically transmitted through the soil into groundwater. Otherwise, porous pavements shall generally be analyzed as a gravel surface (road or parking lot) with normal runoff coefficients used for the Rational formula or for SCS methods of drainage design.

Porous pavement is usually a modular pavement grid, although pour-in-place concrete and asphalt can be made into porous pavement also. See Figure I-04-2 for a few sample types of porous pavement (taken from *The Florida Development Manual: A Guide to Sound Land and Water Management, 1988*), for which grass is allowed to grow between the grids. A less durable variation can be made with bricks, placed on sand bedding and filled in with soil, with approximately 50% brick surface. Porous pavements have been proven to be not durable under street traffic, and should be restricted to light traffic conditions without heavy trucks. Porous pavements are particularly recommended for residential driveways or overflow parking lots.

Porous pavements are likely to absorb large amounts of pollutants from automobiles, such as heavy metals and petroleum products. Porous pavements should be cleaned regularly using methods that will not dislodge the grass, sand or soil from between the concrete grids. Collect washwater and dispose properly to avoid washing pollutants downstream.

Construction/ Inspection Considerations

- It is very important to protect the natural infiltration rate by using light equipment and construction procedures that minimize compaction. Stormwater must be allowed to enter the facility until all construction in the catchment area is completed and the work area is stabilized. If this prohibition is not feasible in particular situations, do not excavate the facility to final grade until after all construction is complete upstream. With trenches, make sure the rock fill does not become dirty while temporarily stored at the site.
- Protect infiltration surface during construction.
- Inspect frequently for clogging during construction.
- Prevent erosion and sediment transport from occurring upstream of an infiltration basin or other infiltration system.

Maintenance

- Maintenance can be difficult and costly for most infiltration systems, with a potential for high maintenance costs due to clogging. Maintenance costs and site access should be carefully considered prior to design.
- Pretreatment of stormwater runoff may reduce maintenance costs by capturing coarse sediments and floatable materials in a smaller structure that can be more easily cleaned.
- Inspect and observe the infiltration system several times during the first year, particularly after heavy rainfall events. Use observation wells and cleanout ports to monitor water levels and drawdown times. Record all observations and measurements taken. Perform any maintenance and repairs promptly.

- Remove debris and sediment at least annually to avoid high concentrations of pollutants and loss of infiltration capacity.
- Vacuum sweeping and jet hosing are the two primary maintenance requirements that protect the porous pavement from premature clogging. These simple practices are commonly overlooked and failure of the facility soon follows.
- The primary objective of maintenance and inspection activities is to ensure that the infiltration facility continues to perform as designed. Regular inspection can substantially lengthen the required time interval between major rehabilitations.
- Prevent compaction of the infiltration surfaces by physical controls such as gates or fences. Maintain dense grass vegetation for infiltration basins. Use rotary tillers on infiltration surfaces when needed to restore infiltration capacity and to control weed growth.
- Maintain records of inspections and maintenance performed.
- Porous pavement resurfacing must only completed with the proper materials, as approved by the municipality's engineering department.

Sediment Removal

A primary function of stormwater treatment BMPs is to collect and remove sediments. The sediment accumulation rate is dependent on a number of factors including watershed size, facility sizing, upstream construction, nearby industrial or commercial activities, etc. Sediments should be identified before sediment removal and disposal is performed. Special attention or sampling should be given to sediments accumulated from industrial or manufacturing facilities, heavy commercial sites, fueling centers or automotive maintenance areas, parking areas, or other areas where pollutants are suspected. Treat sediment as potentially hazardous soil until proven otherwise.

Some sediment may contain contaminants for which TDEC requires special disposal procedures. Consult TDEC – Division of Water Pollution Control if there is any uncertainty about what the sediment contains or if it is known to contain contaminants. Clean sediment may be used as fill material, hole filling, or land spreading. It is important that this material not be placed in a way that will promote or allow resuspension in stormwater runoff. Some demolition or sanitary landfill operators will allow the sediment to be disposed at their facility for use as cover. This generally requires that the sediment be tested to ensure that it is innocuous.

Cost Considerations

There is potential for high maintenance costs due to clogging, but pretreatment will reduce maintenance costs by capturing gross settleable solids and floatables in a smaller space that can be more easily cleaned. In addition, the asphalt used in porous pavement costs more than conventional pavement. It can cost up to fifty percent more than conventional asphalt. However, without the additional need for stormwater drainage, conveyance, and off-site treatment, porous pavement can be very cost effective.

Limitations

- The four major concerns with infiltration systems are clogging, potential impact on other structures and properties, accumulation of heavy metals, and the potential for groundwater contamination.
- Clogging and high maintenance costs are very likely to occur in fine soils that are marginally allowable for infiltration rates. Erosion control is extremely important to prevent clogging; infiltration systems fail if they receive high sediment loads. Perform regular maintenance and inspections to minimize the potential for clogging and loss of infiltration capacity. Pretreatment is highly recommended for stormwater runoff from many land uses, prior to discharging to an infiltration system. Erosion of the side slopes is a major factor in clogged infiltration basins.
- Porous pavement has high failure potential (~ 75%) (Schueler et al, 1992). The main causes of failure are clogging of the surface by sediment deposits and non-porous resurfacing materials, poor design, low permeability soils, and heavy vehicular traffic. Porous pavement has a tendency to clog after just one to three years (ASCE, 1998).
- There is a concern for toxic chemical leaching from the asphalt.
- Hydrocarbons from vehicles can be transported on porous pavement and lead to clogging of the surface.
- Infiltration systems are not appropriate for areas with high groundwater tables, steep slopes, lots of underground infrastructure, and nearby buildings.
- Porous pavement is not recommended in areas with expectations of high wind erosion, colder climates, and sole-source aquifers.
- Heavy metals are likely to settle in any of the stormwater treatment BMPs, but particularly for infiltration systems (which have the lowest velocity). High levels of heavy metals have been observed in other states where adequate maintenance was not performed. Toxic levels are not likely to be exceeded, but the sediments will need to be handled as hazardous waste after a few years of neglect.
- There is a higher risk of groundwater contamination in very coarse soils. It is highly recommended that a monitoring and inspection program should be used to verify that no contamination occurs. Infiltration systems may not be appropriate where there is significant potential for hazardous chemical spills.
- Porous pavement is suitable only for small sites between ¼ and 10 acres.
- Use of salt and sand for snow removal can promote clogging of the pores and prevent passage of runoff for exfiltration.

Additional Information

- Infiltration systems or wet detention should be considered where dissolved pollutants discharging to surface waters are of concern. However, satisfactory removal efficiencies require soils that contain loam. Coarse soils are not effective at removing dissolved pollutants and fine particulates before the stormwater reaches the ground water aquifer.

- Problems can be expected with infiltration systems placed in finer soils. The State of Maryland has emphasized these systems for about 10 years where they have been installed in soils with infiltration rates as low as 0.27 inches (0.69 cm) per hour. A recent survey (Lindsey, et al., 1991) found that a third of the facilities examined (177) were clogged and another 18% were experiencing slow infiltration. Dry wells that treat roof runoff had the fewest failures (4%) and porous pavement the most (77%). Dry wells may have the lowest failure rate because they only handle roof runoff. The primary causes of failure appear to be inadequate pretreatment and lack of soil stabilization in the tributary watershed, as well as poor construction practices (Shaver, personal communication). Erosion of the slopes of infiltration ponds was a significant problem in almost half the facilities surveyed.
- Based on a review of several studies of infiltration facilities in sandy and loamy soils, it has been concluded that "monitoring . . . has not demonstrated significant contamination . . . although highly soluble pollutants such as nitrate and chloride have been shown to migrate to ground water" (USEPA, 1991). However, pollution has been found in ground water where infiltration devices are in coarse gravels (Adophson, 1989; Miller, 1987).
- Clogging has not been a problem with well maintained systems discharging to sands and coarser soils, suggesting that pretreatment for these infiltration devices in the aforementioned soil conditions is not necessary. Pretreatment when infiltrating to finer soils is suggested. An infiltration facility sized only for treatment is much smaller than one sized for flood control and therefore may be more susceptible to clogging.
- For small systems treating less than a few acres of pavement, pretreatment can be accomplished with a stormwater quality inlet, catch basin and a submerged outlet. The diameter and depth of the sump should be at least four times the diameter of the outlet pipe to the infiltration system (Lager, et al., 1977). Swales can also be used although they will not likely be feasible in industrial sites that tend to be fully utilized.
- For porous pavement, experience in Maryland suggests that asphalt pavement has continuous plugging problems and a limited life. Frequent maintenance is required. Porous pavement should be cleaned at least twice per year by vacuum sweeping and high-pressure washing.
- Two long-term studies conducted in the Washington area by the Occoquan Watershed Monitoring Laboratory indicate quite high removal capabilities: 85% - 95% mass removal of solids, 65% total phosphorus, 75% - 85% total nitrogen, and ~98% removal of trace metals (Schueler et al, 1987).
- Porous pavement protects downstream aquatic life by maintaining water balance at the site, minimizing streambank erosion, and filtering out pollutants.
- Using porous pavement rather than conventional pavement causes vehicles to be less susceptible to hydroplaning and have better skid resistance.
- Porous pavement can improve visibility during rain because of its ability to infiltrate water quickly.

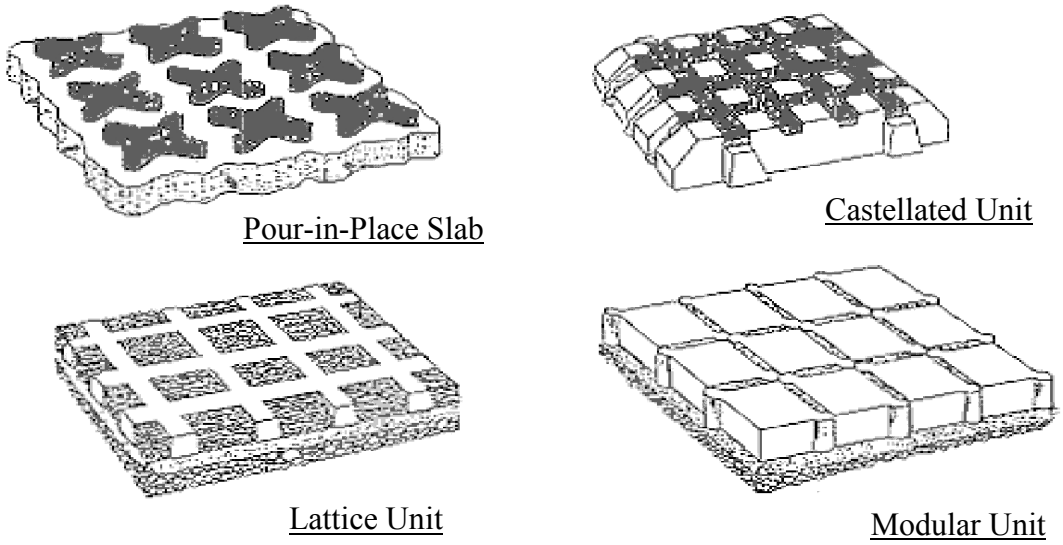


Figure I-04-2
Examples of Porous Pavement Systems
(Florida Manual, 1988)

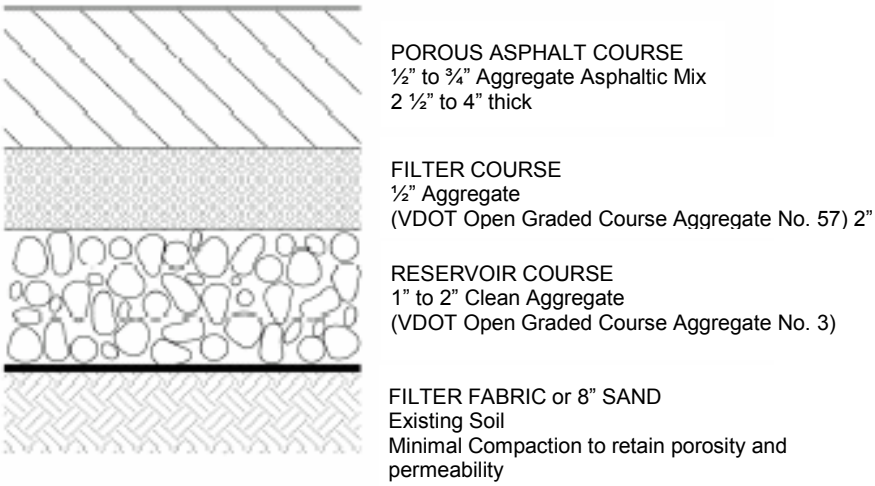


Figure I-04-3
Porous Pavement Section

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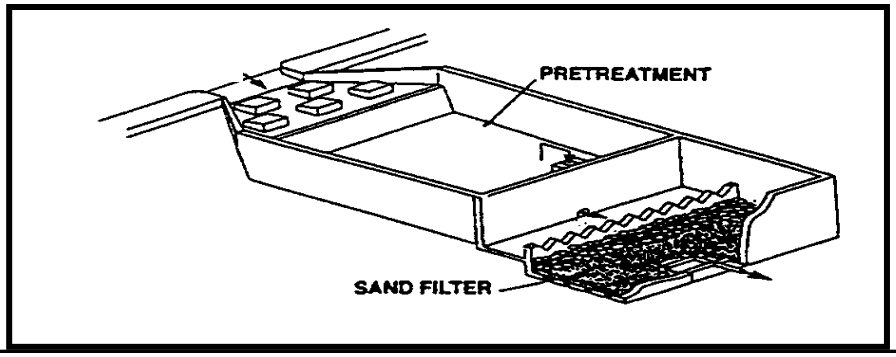
Filtering Systems

ACTIVITY: Catch Basin Inserts / Media Filter

F – 01



Targeted Constituents				
● Significant Benefit		◗ Partial Benefit		○ Low or Unknown Benefit
● Sediment	◗ Heavy Metals	◗ Floatable Materials	◗ Oxygen Demanding Substances	
◗ Nutrients	◗ Toxic Materials	◗ Oil & Grease	◗ Bacteria & Viruses	○ Construction Wastes
Implementation Requirements				
● High		◗ Medium		○ Low
● Capital Costs	◗ O & M Costs	◗ Maintenance		○ Training

Description

This stormwater treatment BMP addresses a variety of water quality enhancing inlets, consisting of modified catch basins and media filtration inlets, with oil/water separators being specifically addressed in F-02.

Modified catch basins contain an oversized sump, and also some type of inflow and outflow control to remove coarse sediments and floatable materials. Modified catch basins are effective as a pretreatment measure for other BMPs, but are not sufficient to provide stormwater treatment as a stand-alone measure.

Catch basin inserts are a relatively new type of technology in the realm of stormwater quality best management practices (BMP's). This technology involves the placement of devices that contain a filtering media (a sorbent) just under the inlet of a storm drain. Runoff flows into the inlet and through the filter where the targeted contaminants are removed. They can be an effective means of petroleum hydrocarbon control, thereby reducing non-point source pollution.

Media filtration inlets use materials such as sand, peat, screens, patented sorbent paper media, or cloth to filter stormwater runoff. Sand filtration inlets can be constructed in a variety of layouts using precast vaults, paved trenches, or in earthen or concrete basins. Media filtration systems are available commercially with a wide range of materials and methods for easy installation and operation. Media filtration inlets will create a partial reduction in most pollutants only if they are inspected, cleaned and maintained on a regular basis. A layer of organic material (such as peat moss) or potentially some types of clay can increase the removal of metallic ions and organic pollutants from stormwater runoff.

Selection Criteria

There are several models or designs of catch basin inserts on the market, which can meet site specific conditions. Catch basin inserts are not designed to be a stand-alone BMP but rather to be used as a first flush treatment practice prior to a storm drain network, detention/retention facility, infiltration practice, or some other form of water quantity control measure. They are usually applied in highly urbanized areas, where space is not available for more effective BMPs.

- Modified catch basins (with enhanced capability to capture coarse sediments and floating debris) and media filtration inlets may be used on commercial and industrial properties that have parking lots and vehicle traffic. This type of land use is likely to receive salts and sands for removing ice and snow, trash from vehicles, leaking oil and grease, and leaves and dirt from landscaping.

- Water quality enhancing inlets may be used for most impervious properties with parking lots and vehicle traffic. They are also highly recommended for commercial and industrial sites that generate fine particles, sediment, tailings, sawdust or other pollutants for which a media filtration inlet would be effective.

- Media filters are primarily used for water quality control, although they do provide detention and slow release of treated water. Additional calculations will be required to check for proper detention.

Design and Sizing Considerations

The various types of water quality inlets should be selected according to targeted constituents, site area constraints, cost and frequency of maintenance, and inspection requirements. Media filtration inlets can essentially be designed to filter any particle size and particle type imaginable at low to moderate flow rates. Many filtration systems are readily available from commercial vendors in a variety of sizes, layouts, and targeted pollutants. Water quality inlets can be designed for new property uses or can often be retrofitted onto existing stormwater drainage systems.

Catch basin inserts are not capable of handling large amounts of runoff volume, but are sufficient in providing water quality improvement in low-density areas. Catch basin inserts generally perform best when they serve parking lots less than 1 acre in size or urban roadways. In most situations, they must be used in conjunction with other water quantity BMPs to meet stormwater management criteria.

A very important decision to be evaluated is the ability to bypass or convey large storm events that have the potential to damage the BMP system or re-suspend collected pollutants. Figure F-01-1 shows one method for allowing high-flow stormwater to bypass the BMP system; there are many other types of flow-splitting structures that allow the BMP system to function “off-line” rather than “on-line”. The minimum requirement for water quality inlets (including media filtration inlets) is to treat the first flush volume.

Due to the precast nature of this BMP, the engineer or planner who is responsible for the installation and operation of the catch basin insert needs only to be concerned with determining the site-specific characteristics. The volume of the water that is to be treated must first be determined (i.e., first flush, entire 2-yr storm, etc.). Once the volume is found, a hydrologic analysis must be determined the actual volume of runoff that the insert will treat. The dimensions of the catch basin that is collecting the runoff must be determined in order for the manufacturer to correctly fabricate the BMP and assure that the insert will not be the limiting factor when it comes to passing the design flow. The design engineer also needs to estimate the types and amounts of pollutants the catch basin will trap.

Some advantages of water quality inlets are:

- Does not require a supply of water (such as wet detention basins or wetlands).

- Can be placed underground as part of the storm drainage system.
- Suitable for smaller catchments including parking lots and roadways.
- Many types of filters are suitable for larger drainage areas up to 5 or 10 acres.
- Sand or cartridged media filters may be particularly suitable for industrial sites because they can be located underground and industrial facilities generally have the resources to routinely inspect and maintain the systems.
- There can be marked reduction of hydrocarbon loadings from areas with high traffic/parking volumes.
- The underground placement is not generally noticeable and therefore does not make this BMP aesthetically unpleasant.
- Their underground placement does require the utilization of valuable space in highly urban areas.
- This BMP can also be retrofit into most existing catch basins without additional construction.

This BMP fact sheet discusses the general uses of modified catch basins and media filtration inlets. The practices presented in F-02, Oil/Water Separator, should also be reviewed when oil and grease are likely to be present in stormwater runoff.

A typical modified catch basin, as shown in Figure F-01-2, will capture coarse sediments and floating debris. A modified catch basin could have many possible variations that will essentially perform the same function. The modified catch basin must have removable elements to allow inspection and cleaning of all pipes.

A sand filter is probably the most common type of media filtration system used. Figure F-01-3 shows a surface sand filter system, which is easier to inspect and usually less costly than an underground sand filter system. The detail shown can be sized to handle several acres. Filter cartridges or other media may also be acceptable alternatives to using sand if maintenance and operation considerations are addressed.

Figure F-01-4 shows a manufactured BMP media filtration system called StormFilter, manufactured by Stormwater Management Inc. It is similar to the sand filter vault (shown in Figure F-01-6), except it uses media cartridges instead of sand. The internal valving, hardware and cartridges are installed into a precast concrete vault. Media cartridges are especially useful for industrial sites where specific types of particles can be targeted. Media cartridges can be designed to target specific pollutants such as sediments, oil and grease, organics, heavy metals, and soluble nutrients. StormFilter requires 2.3 feet of head differential across the unit to work properly. SMI also makes a high-flow bypass system called StormGate. Contact manufacturer for design and installation details and pricing at

http://www.stormwaterinc.com

Two different types of underground sand filter layouts are also included as details. Underground filtration systems are more difficult to inspect and maintain. On the

other hand, underground filtration systems are protected from weather and other hazards, and do not take up valuable real estate. Underground systems may exhibit odor problems during the summer because of a lack of bacterial degradation of accumulated organic matter and a lack of aeration within the wet pool.

The Delaware sand filter (Figure F-01-5) is suitable for overland sheet flow from paved areas such as commercial properties or industrial sites. Originally designed by Mr. Earl Shaver for the state of Delaware, it has two parallel concrete trenches or vaults. The first concrete trench serves as a sedimentation basin and storage facility to evenly distribute water across the sand filter in the second concrete trench. A clearwell is located at the end, with room for an overflow weir and underdrain system to outlet.

The underground sand filter (Figure F-01-6) handles concentrated flow after it has already been collected within a storm drainage system. The front end of the system helps to trap sediment and floatable materials prior to entering the sand filter. The underground sand filter should contain an overflow bypass within the vault, or alternatively a flow-splitter prior to the system.

Figure F-01-7 shows a grate inlet filter insert that uses trays to improve stormwater quality. Figure F-01-8 shows a grate inlet filter insert that uses sorbent material to capture oil and grease. Some special types of sorbent material are durable and strong enough to remain in a filter tray for months, with exceptional capacity for absorbing oils and grease. Figure F-01-9 shows two types of catch basin modifications that will produce clog-resistant media filtration inlets. In general, catch basin filter inserts should only be used wherever maintenance staff is available to check the filters frequently and where local flooding will not occur if the filters should clog. Some companies manufacture the insert frame (stainless steel or fiberglass), which can generally be fabricated in any size to match an existing or proposed inlet. The filter medium typically consists of a blown polypropylene filter with a dacron outer scrim, which is designed to handle oils, grease, PCBs and sediments. Contact manufacturers for design and installation details and pricing at:

http://www.remedialsolutions.com
http://www.suntreetech.com.

Two media filtration inlet manufacturers are included in this BMP. Manufactured systems should be selected on the basis of good design, suitability for desired pollution control goals, durability of materials, ease of installation, and reliability. The products listed here are not intended to be a specific endorsement or recommendation. It is incumbent upon the property owner and developer to carefully investigate the suitability and overall trustworthiness of each manufacturer and/or subcontractor.

Media filtration systems are most effective under smaller flow volumes such as the first flush volume. Although media filtration systems must have a buildup of water above the media in order to function, they are generally not effective under conditions of heavy rainfall or floods. Furthermore, some systems can be damaged or the pollutants could be resuspended if operating under high-flow or flooding conditions. To prevent overloading filtration systems, there should be a mechanism to bypass or divert large flows. Commercially available systems may have a high-flow bypass built into the equipment. Other systems may require construction of an overflow bypass weir or other structure.

There are no design requirements for a modified catch basin, other than the minimum

dimensions shown in Figure F-01-2. Extra attention may be required for multiple inlet pipes or special flow conditions, possibly requiring a larger size for a catch basin.

When using commercial products such as water quality inlets, the manufacturer's recommendations should be considered in the product sizing and applicability. Verify that adequate stormwater treatment is provided and that high-flow bypass methods do not hinder the system from adequately treating the first flush volume.

A major drawback for a media filtration inlet is the need for elevation differences in the storm drainage system. A media filtration typically needs at least 5 feet of head loss available across the system, in order to accommodate live pool storage and sand filter thickness.

The liner or concrete shell of the sand filter should be placed at least 2 to 4 feet above the seasonally high ground water table or bedrock. This minimizes the infiltration of groundwater into the filter.

Filtration Volume:

The volume of the live pool for a sand filtration or other media filtration system shall usually be the first flush volume, which is intended to be slowly released through the filtration device after being treated. The live pool may include any storage capacity of incoming pipes and catch basins that is clearly not part of the dead pool volume. The dead pool volume is the portion of the filtration system which always has water (such as underground sand filters). Some examples of live pool volumes are shown in Figures F-01-3, F-01-5, and F-01-6. Larger filtration volumes are typically much easier to accommodate within an open system such as the surface sand filter.

Filtration Surface Area:

Many equations have been proposed to determine the surface area of a sand filter, including that used by the city of Austin TX and throughout the state of Virginia (Austin (city of), Texas, 1989 and Virginia Department of Conservation and Recreation, 1999). Proper gradation of sand filter must be achieved. Additional design criteria for the surface sand filter (Figure F-01-3) include:

- Size the control orifice or perforated riser pipe to allow for a 24-hour drawdown time, in conjunction with allowable sand filtration loading rate.
- Provide an energy dissipater prior to the sedimentation basin to reduce turbulence. Consider using some type of flow-splitter immediately upstream of a surface sand filter.
- Typical length-to-width ratio of the sedimentation basin should be at least 3:1 (L:W) to prevent possible shortcutting. Allow for a minimum freeboard of 6". Provide easy vehicle access to basin for maintenance and cleaning.

Additional design criteria for the Delaware sand filter (Figure F-01-5) and the underground sand filter (Figure F-01-6) include:

- The live pool volume typically is the most stringent requirement to meet. An adjacent vault may be needed to provide additional live pool volume. Ensure that stormwater runoff flow entering the sand filter is distributed evenly.

- Structural design should be performed by a professional engineer in areas where traffic loading is a concern. Otherwise, prevent vehicles from driving onto any type of underground structure while ensuring nearby access.

- Provide baffled walls to reduce entrance velocities. The front portion of the structure should contain a dead storage pool to retain floatable materials and sediment. For ease of inspection and maintenance, limit the depth of the dead pool volume to less than 4 feet.

- Provide adequate access for inspection, cleaning and maintenance activities for each chamber. Removable access covers are recommended for chambers that do not have adequate standing room. Provide steps or rungs as needed.

- Use geotextile fabric on top of the sand layer to prevent displacement. Use geotextile fabric beneath the sand layer to prevent loss of material through the gravel underdrain layer. A typical underdrain pipe is 4" diameter schedule 40 PVC pipe, with 3/8" perforations around the pipe diameter at 6" spacing. Place underdrains at 5' lateral spacing with a 1% to 2% positive grade.

A pretreatment sedimentation basin is essential to avoid rapid clogging of the filter medium. Since peat seems to be very effective at removing dissolved contaminants such as heavy metals, there has been research into using peat/sand mixtures (Galli, 1990 and Tomasak, Johnson, and Mulloy, 1987) which are subject to clogging problems. Research has also indicated that compost made from leaves is very effective at removing dissolved phosphorus and metals, and oil and grease (Stewart, 1989). Field research at Austin, Texas in 1990 indicates that the surface sand filter has a removal efficiency of total suspended solids that is similar to wet and dry detention basins: about 70 to 90%. Removal rates for heavy metals, oil and grease vary from 20% to 80%, depending on the application.

Consult references for additional design and maintenance criteria. Inspection and maintenance frequency will also greatly affect pollutant removal rates.

Catch Basin Inserts

Catch basin inserts are ideal for industrial sites as they fit into existing catch basins, and therefore may avoid the need for an "end-of-pipe" facility. Typical catch basin inserts are shown in Figures F-01-7 and F-01-8, consisting of a series of trays or sorbent roles/tubes. The top trays are designed to capture coarse sediments, and lower trays may capture finer sediments or specific pollutants. Inserts made from fiberglass insulation materials can achieve up to 90% removal for heavy metals, oils and grease (McPherson, 1992). Since catch basin inserts require frequent inspection and maintenance, they should only be used where a full-time maintenance person is located on the site (typically at large commercial or industrial facilities). A typical insert design may have a high-flow bypass and should be hydraulically designed to allow stormwater runoff into the drain system without danger of local flooding. A list of insert manufacturers can be found in Table F-01-1.

Construction/ Inspection Considerations

Devices should be installed in accordance with manufacturer specifications.

Catch basin inserts will not function properly if clogged with sediment and debris, and therefore most of the designs are not recommended near construction areas without appropriate sediment control. There are some inserts that are designed especially for the removal of high sediment loads from construction sites.

Maintenance

- Inspect modified catch basins and media filtration systems on a regular basis, typically every month and after heavy rainfalls. Record observations in an inspection log and take pictures as necessary to document conditions. Make immediate repairs as needed. Clean or replace filtration media as needed to prevent clogging.
- Perform cleanout on a regular basis using confined-space procedures and equipment as required by OSHA regulations, such as nonsparking electrical equipment, oxygen meter, flammable gas meter, etc. Remove trash, debris, sediments or clogged media as needed, and then dispose of them properly. Sediments or clogged media may contain heavy metals or other toxic substances and should be handled as hazardous waste. Removal of sediment or clogged media depends on the accumulation rate, available storage, watershed size, nearby construction, industrial or commercial activities upstream, etc. Sediment or clogged media should be tested for identification of pollutants prior to disposal.
- Some sediment may contain contaminants for which the Tennessee Department of Environment and Conservation (TDEC) requires special disposal procedures. Consult TDEC - Division of Water Pollution Control if uncertain about what the sediments contain or if it is known to contain contaminants. Generally, give special attention or sampling to sediments accumulated in industrial or manufacturing facilities, fueling centers or automotive maintenance areas, large parking areas, or other areas where pollutants are suspected to accumulate.
- It is generally more cost efficient to clean the filtration media. For sand filters, cleaning or replacement of the top few inches may restore the permeability rate. Failure to clean the filter surface regularly may result in the need to replace the entire media because of penetration of fines into the filter.
- A very important consideration is the allocation of long-term resources for inspection, maintenance and repair. Water quality enhancing inlets should only be constructed if: 1) there is a maintenance plan to regularly inspect and maintain inlets on a long-term basis, and 2) there is an agreement or fiscal guarantee that the required maintenance resources will be available throughout the operation life of the water quality inlets. Without regular inspection and maintenance, a water quality inlet will fail and generally create a worse pollution problem than having no inlet at all.
  - Routine maintenance procedures, although frequent, are not overly time consuming relative to BMPs such as retention/detention ponds, infiltration trenches, and constructed wetlands.
  - It is important to keep the filters clean. Any debris, sediment, grass clippings, etc. should be removed from the system and properly disposed.

Cost Considerations

Insert cartridge replacements and maintenance can be expensive, depending on specific type of system used. Table F-01-1 compares costs, applications, and removal efficiencies for several types of catch basin inserts.

As a whole, this BMP is relatively expensive, considering the limited pollutant removal capabilities under typical field conditions and the relatively frequent need for replacement.

Limitations

- Media filtration systems and modified catch basins will require more frequent inspection and maintenance than most other stormwater treatment BMPs. Filtration media will need to be cleaned and/or replaced frequently. There is very high potential for severe clogging or reduced pollutant removal efficiency in filtration systems, particularly if there are unstabilized soil surfaces upstream. Do not operate filtration systems until upstream erosion areas are controlled.
- Media filtration systems cause a large head loss that may require special consideration in the hydraulic design of the overall stormwater collection system. Systems may typically require vertical filtration through at least 18 inches of sand and 6 inches of underdrain material, for an absolute minimum head loss of 2.5 feet.
- There is a possibility of pulse loadings due to resuspension of pollutants from dirty filters during intense storms.
- It is difficult to dispose of spent filter media in methods that are environmentally sound and cost-effective.

Additional Information

Additional information can be found on the following pages.

Type of Insert	Applications	Target Pollutants	Capital Costs	Maintenance Frequency	Filter Longevity	Oil and Grease	Heavy Metals	TSS
AquaShield	New and existing industrial, commercial, governmental, institutional, & multi-family developments	Oil & Grease, TSS, Nutrients, Heavy Metals, BOD	$997 to $3250	After rainfall > 0.5" in 24 hours; Prior to wet season; After treating 10x design flow capacity	~ 3 months	98%	86%	82%
BMT Storm Clenz Filter	Areas of high hydrocarbon loading, accompanied by low sediment volumes	Sediment & petroleum hydrocarbons	$350 to $800	3x per year; prior, during, end of wet season	3 to 4 months	Absorbs 5x its weight	No specific claims	No specific claims
Enviro-Drain	Parking lots, downtown areas, residential/commercial/industrial areas	Hydrocarbons, organics, sediment, heavy metals, nutrients, debris	$4500	From after every major rain event to after >5 inches of rain	At least every 3 months	97%	97%	97%
Fossil Filter	Anywhere motor vehicles move, park, refuel, or are serviced	Oil & grease, gasoline, diesel fuel	$400	At least 3x / yr; Once prior to main wet season and twice during	~ 6 months	98%	No specific claims	No specific claims
Gullywasher	Parking lots, residential & downtown streets, commercial areas	Petroleum hydrocarbons, sediment, debris	$450 to $700	From after every major rain event to after >5 inches of rain	At least every 3 months	No specific claims	No specific claims	No specific claims
Hydro-Cartridge	Parking lots, roadways	Sediment and petroleum hydrocarbons	$680 to $1160	2 weeks to 1 month	6 to 8 months	> 90%	No specific claims	> 90%
SIFT Filter	Areas of high hydrocarbon loading	Petroleum hydrocarbons	$350 to $700	6 months to 1 year	6 months to 1 year	99.4%	No specific claims	No specific claims
SiltSack	Construction sites & other land disturbing activities	Suspended sediment	$70	After every major rain event	Highly variable	98%	98%	98%
Storm Watch	Areas of high hydrocarbon loading, Construction sites	Sediment & petroleum hydrocarbons	$63 to $125	After every major rain event	3 months to 1 year	93% *	No specific claims*	81% *
Stream Guard	Construction sites, Areas of high vehicle volume or exposure, Stadiums, Shopping malls, Downtown streets, Waterfront tourist areas	Oil & Grease, TSS, Trash & Debris	$53 to $89	Trash/Debris Model and Sediment Model - weekly to monthly; Oil & Grease Model - monthly	3 months to 1 year	93%	No specific claims	81%
Ultra-Urban	Areas of high hydrocarbon loading, accompanied by low levels of sediment & debris	Oil & Grease, Sediment, Debris		Every 3 months	~ 1 year	80%	No specific claims	No specific claims

* Removal data for Storm Watch based on Stream Guard, because they have basically same design

Table F-01-1
Catch Basin Insert/Filter Characteristic Comparison Matrix (Wagner, 1999)

A high-flow bypass structure may also be constructed in a rectangular structure or an open channel using diversion weirs.

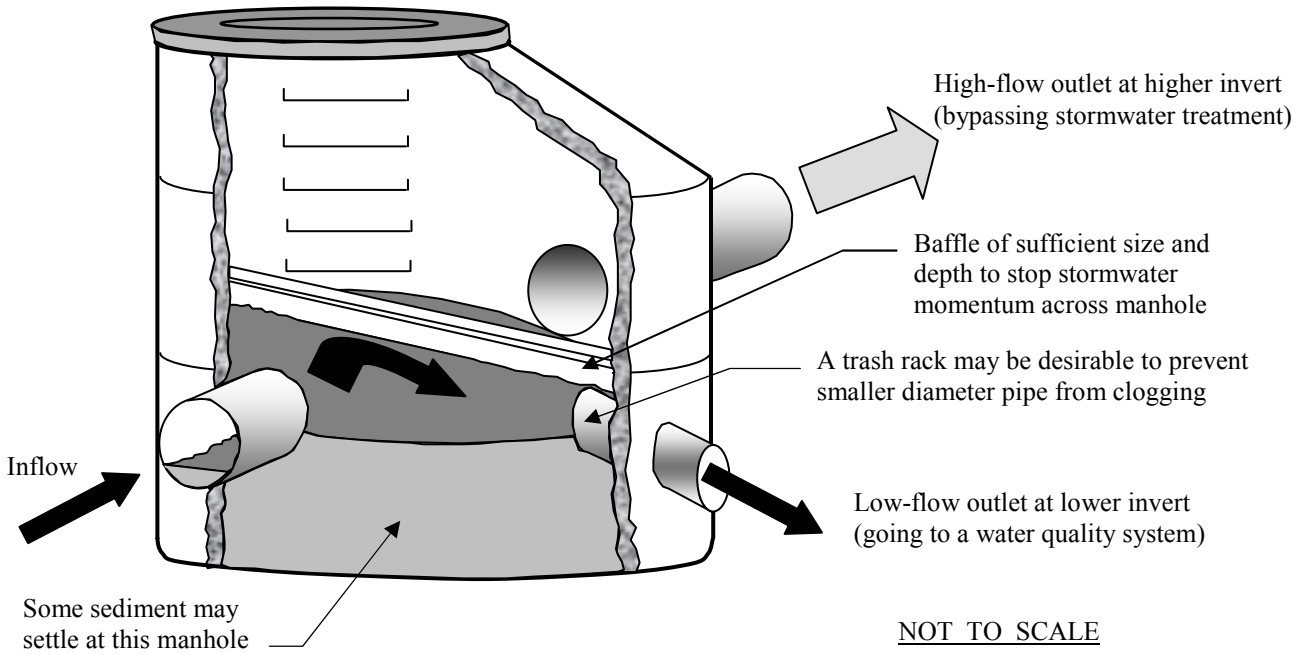


Figure F-01-1
Typical Stormwater High-Flow Bypass Manhole

Notes:

1. Securely attach pipe elbow, tee or cross to the manhole or structure to resist expected flow velocities and forces. Bolts or other removable fasteners should preferably be used. Cross braces or other supports may be necessary.
2. A modified catch basin is a good practice for areas with potential sediment loads, and as a pretreatment unit for most other stormwater treatment BMPs.

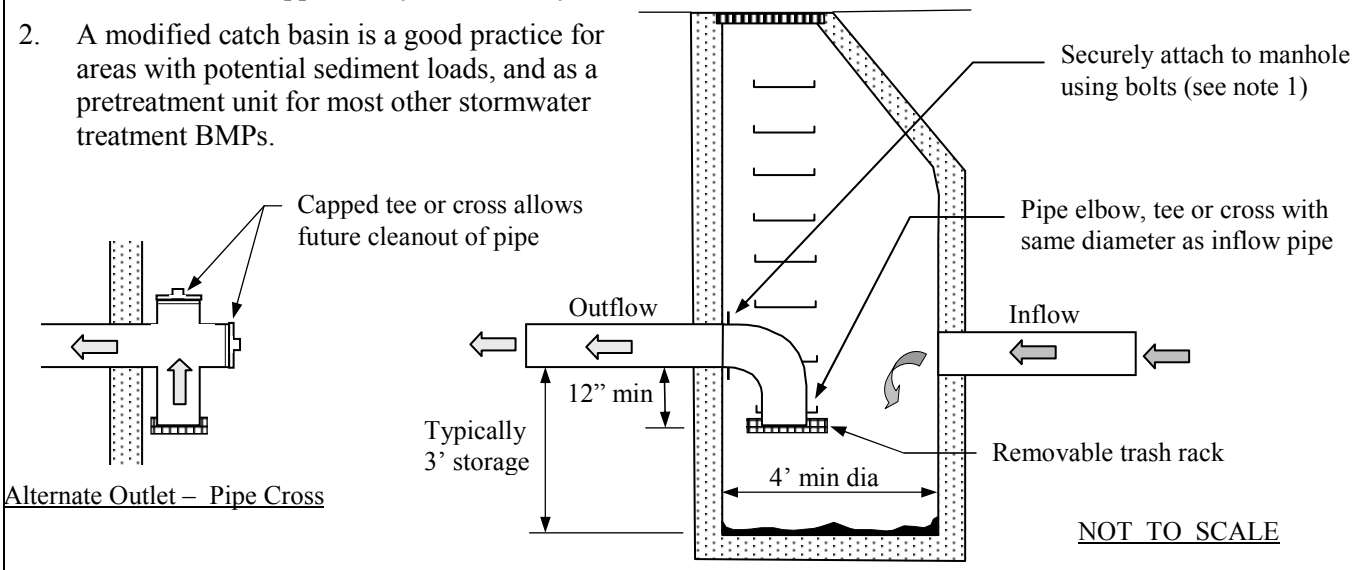


Figure F-01-2
Modified Catch Basin

NOT TO SCALE

Perforated PVC riser (sized to regulate flow to sand filter)

Gravel or riprap (adjacent to weir)

Filtration basin (with sand or cartridge media)

Energy dissipating blocks

Sedimentation basin

Cartridge (alternative)

Plan View

Weir for uniform flow discharge

Incoming surface channel or gutter (may also be a pipe or culvert)

Perforated PVC riser

Sedimentation basin

Live pool

Riprap or gravel

Cartridge (alternative)

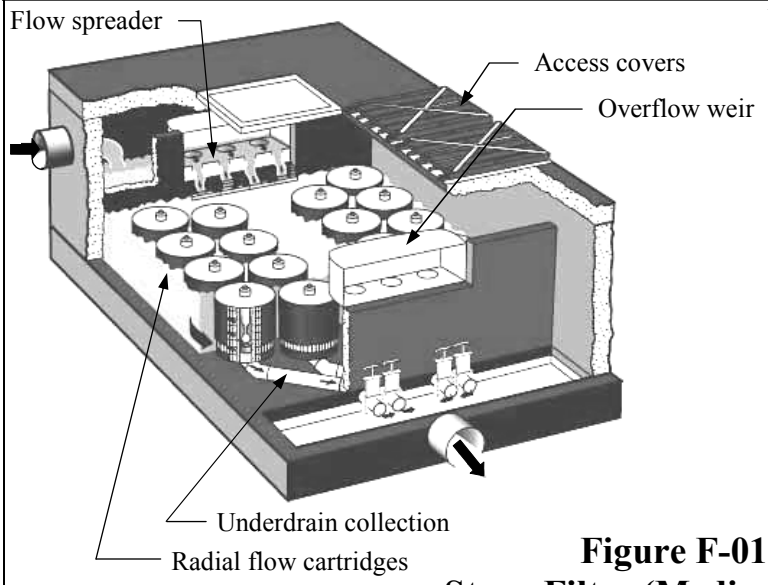
Use trash rack or geotextile fabric over bottom perforations

Elevation

Underdrain piping

Sand bed (typical depth 18")

Figure F-01-3
Surface Sand Filter



Notes:

1. StormFilter is manufactured by Stormwater Management Inc. located in Portland, Oregon. The end product consists of a precast vault (sized by SMI and produced by a local precast vendor) and the necessary valving and hardware. SMI also makes a high-flow bypass system called StormGate. See http://www.stormwaterinc.com for details.
2. Media cartridges can be designed to target specific pollutants such as sediments, oil and grease, organics, heavy metals, and soluble nutrients. The StormFilter requires 2.3 feet of head differential across unit.

Figure F-01-4
StormFilter (Media Cartridge)

NOT TO SCALE

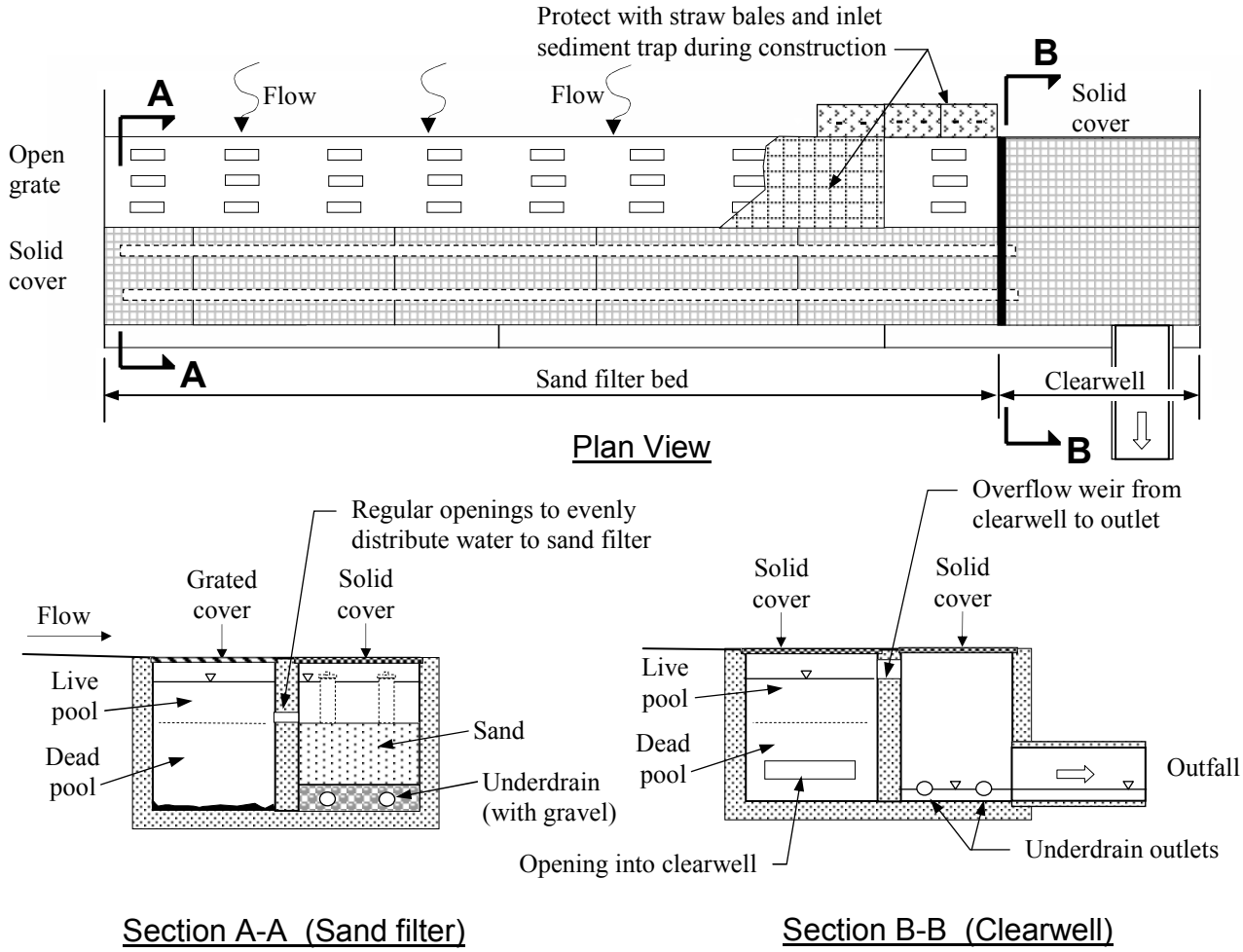
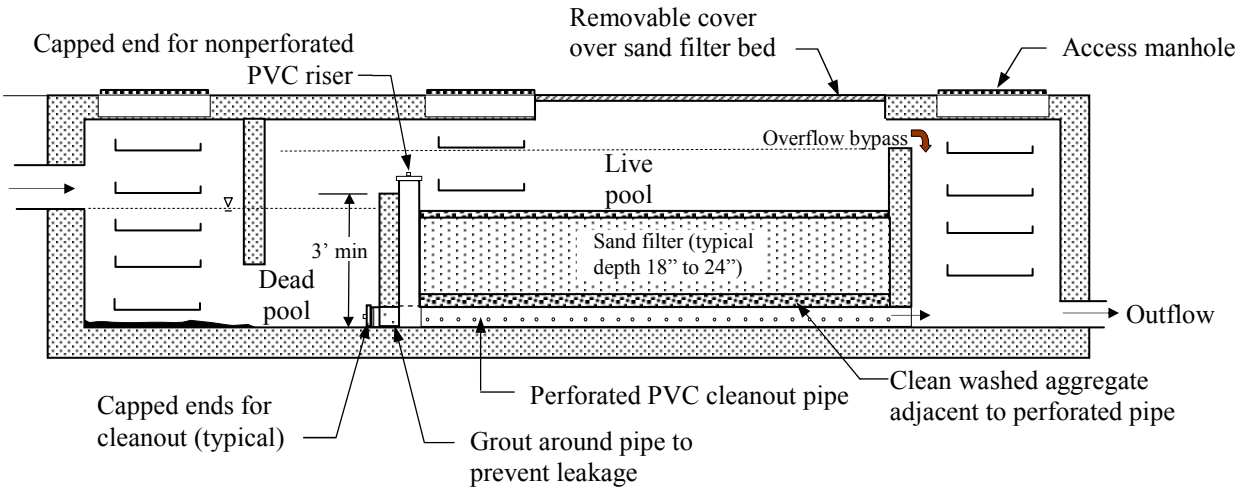


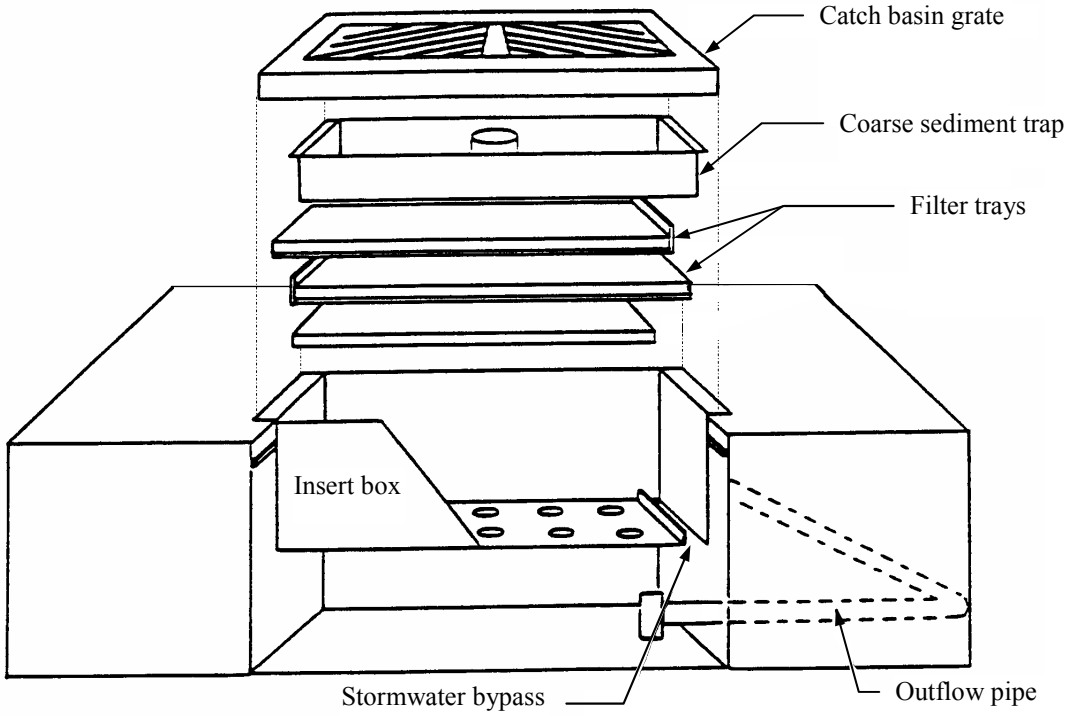
Figure F-01-5
Delaware Sand Filter

NOT TO SCALE



NOT TO SCALE

Figure F-01-6
Underground Sand Filter



NOT TO SCALE

Figure F-01-7
Typical Grate Inlet Filter (with Filter Trays)

Typical manufacturers of grate inlet inserts –

http://www.remedialsolutions.com

http://www.suntreetech.com.

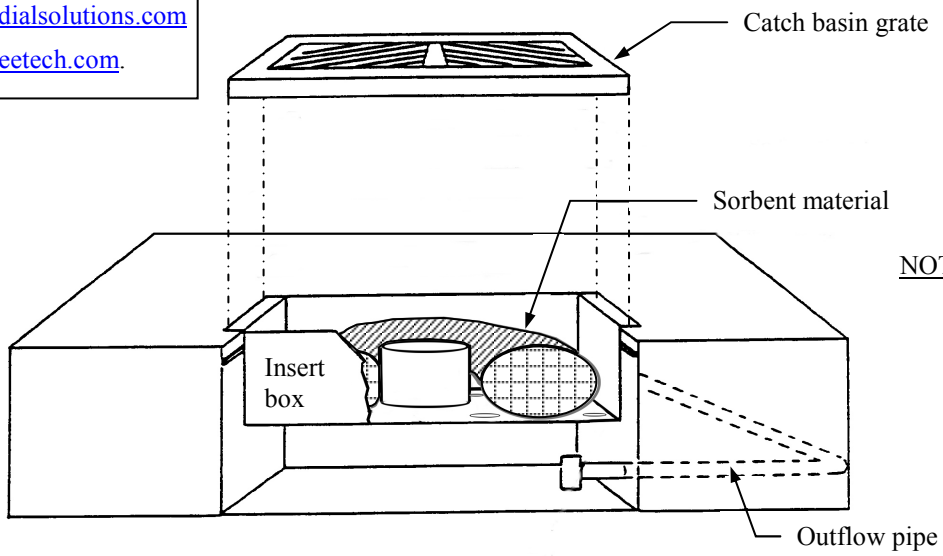


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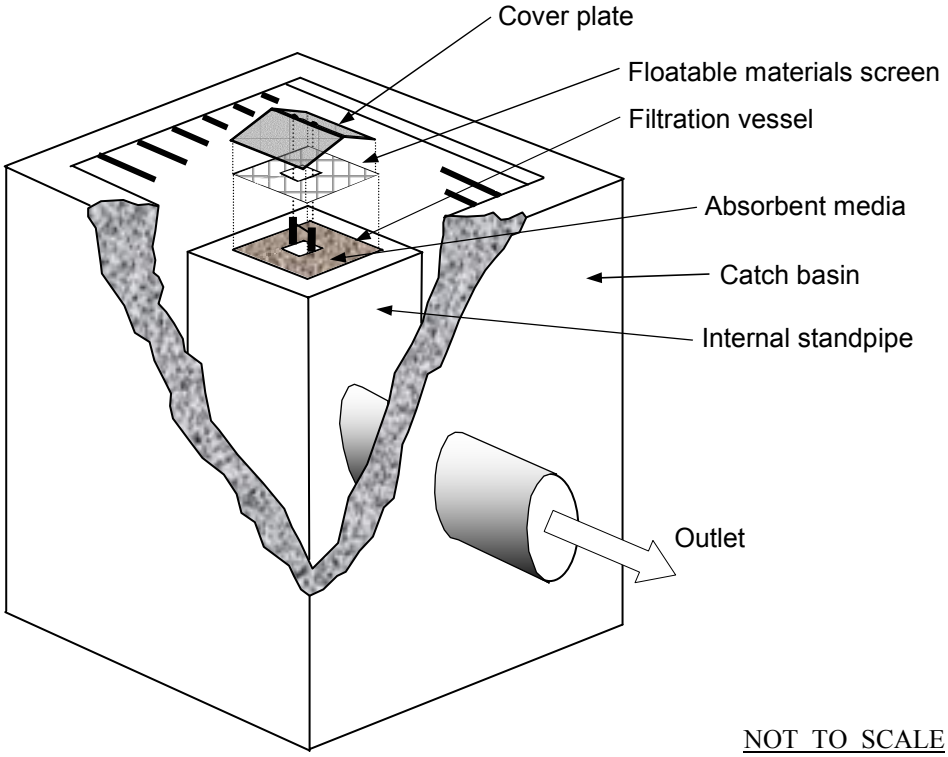
Figure F-01-8
Typical Grate Inlet Filter (with Sorbent Material)



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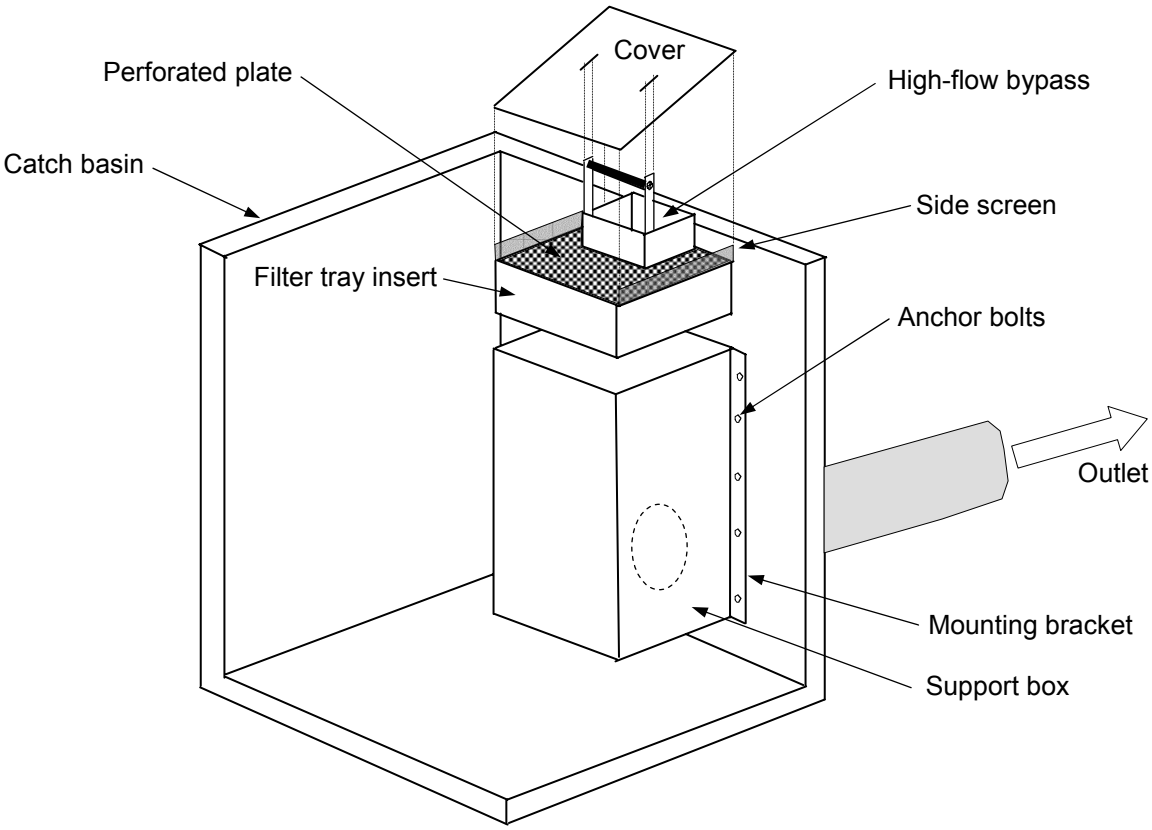

Figure F-01-9
Clog-Resistant Media Filtration Inlets

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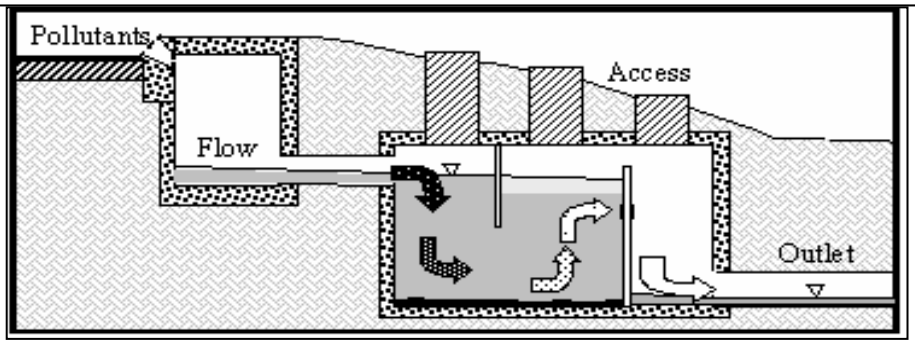
ACTIVITY: Oil/Water Separator

F – 02



Targeted Constituents				
● Significant Benefit		◗ Partial Benefit		○ Low or Unknown Benefit
● Sediment	● Heavy Metals	● Floatable Materials	◗ Oxygen Demanding Substances	
◗ Nutrients	● Toxic Materials	● Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes
Implementation Requirements				
● High		◗ Medium		○ Low
● Capital Costs	◗ O & M Costs	◗ Maintenance		○ Training

Description

Oil/water separators (also called oil/grit separators because most designs generally remove coarse sediment) are intended to remove floating gasoline, oil, grease, light petroleum products and other floating liquids from stormwater runoff. Oil/water separators are especially applicable as pretreatment before detention ponds. See F-01 (Catch Basin Inserts / Media Filter) for similar structures which also have some capabilities for removing oil and grease. Various systems discussed in this BMP should be evaluated for targeted constituents, site area constraints, cost, frequency of maintenance, reliability, and inspection requirements.

There are two basic types of oil/water separators (conventional and CPI), as displayed in Figure F-02-1. Conventional separators rely upon gravity, physical characteristics of oil and sediments, and good design parameters to achieve pollutant removal. CPI separators contain closely-spaced plates which greatly enhance the removal efficiency for oils and grease. In addition, a wide variety of systems are commercially available in a variety of layouts, for which vendors have design data and procedures.

Selection Criteria

Oil/water separators are commonly used for industrial applications, which have a constant flow of known quantity. Separators are very efficient in these types of applications. However, it is much more difficult to remove smaller concentrations (such as 10 ppm) from stormwater runoff which has a much broader range of flows. Due to many unknown variables concerning oil and grease pollutants, theoretical equations for oil separation are not usually applicable for stormwater runoff. There are a wide variety of empirical guidelines when evaluating manufactured oil/water separators. The most important selection criteria are the long-term maintenance and operation costs, regular inspections, and cleanout procedures. The oil/water separator system should only be constructed if: 1) there is a maintenance plan to regularly inspect and maintain the oil/water separator on a long-term basis, and 2) there is an agreement or fiscal guarantee that the required maintenance resources will be available for the life of the system. Without regular inspection and maintenance, an oil/water separator will fail and generally create a worse pollution problem.

Another very important decision is whether to bypass large storm events around the oil/water separator without damaging the system, exceeding design flow capacity, or re-suspending collected pollutants. For larger storm events, stormwater runoff will become turbulent and remix the oil droplets. Large flows can also scour sediments that have been deposited on the bottom of an oil/water separator over the course of several months. Essentially, pollutant removal is only ensured when the oil/water separator is cleaned out regularly, and the sediments are properly analyzed and disposed.

Stormwater runoff is only detained briefly within oil/water separators because of size constraints for an engineered structure. Therefore, it is important that all factors leading up to the separator and also downstream from the separator are favorable for its effective operation. An oil/water separator is frequently used as the upstream pretreatment measure in a series of stormwater treatment BMPs, ahead of a detention basin or constructed wetland. Advantages of an oil/water separator may include:

- Efficient use of valuable space (since it is usually located underground)
- Does not require as much vertical drop as some other types of BMPs
- Easily accessible and easy to clean with proper equipment
- Reliable if carefully designed (including upstream and downstream reaches)

Oil/Water separators are ideal for the following situations:

- Parking lots, streets, driveways, truck loading areas
- Runways, marinas, loading wharves
- Gasoline stations, refueling areas
- Automotive repair facilities, oil-change businesses, fleet maintenance yards
- Recycling or salvage yards which accept automotive equipment
- Commercial vehicle washing facilities
- Pretreatment in combination with detention ponds, infiltration systems, constructed wetlands, etc.

Design and Sizing Considerations

A scientific basis for sizing oil/water separators relies upon the rising velocity of oil droplets and the rate of runoff through the system. However (other than stormwater from oil refineries), there is generally no relevant method for describing the characteristics of petroleum products in urban stormwater. It is known that conventional oil/water separators are probably not efficient for removing oil droplets with diameters smaller than 150 microns. For instance, Figure F-02-2 shows a size distribution for which a CPI oil/water separator would be more effective.

Therefore, design is performed on the basis of engineering judgment and guidelines. Design procedures for commercially available oil/water separators are usually given by simplified tables or graphs based on field testing and observed pollutant removal rates. It is desirable to maintain reasonable dimensions by bypassing larger flows in excess of the 1-year storm rainfall rates (preferably by placing the separator “off-line” rather than “on-line”). An off-line separator can be an existing or proposed manhole with a baffle or other control (shown in Figure F-02-3). Bypass mechanisms must minimize potential for captured pollutants from being washed out or re-suspended by large flows.

Some petroleum products may become attached to coarse sediments which are easily removed in the first chamber. A significant percentage of petroleum products also become attached to fine suspended solids and therefore are not removed by settling or flotation. Consequently, the performance of oil/water separators can be difficult to estimate prior to installation and monitoring.

Conventional Oil/Water Separator

Oil and water do not separate easily. By careful design of upstream and downstream reaches, it is possible to reduce turbulent flows, drop heights, mixing or swirling stormwater runoff, and excessive velocities. It is highly recommended that maximum subbasin size for an oil/water separator should be no larger than 1 acre; this will keep units to manageable sizes and allow for accurate monitoring of stormwater quality.

Figure F-02-4 (based upon Maryland standards and taken from Debo, Thomas, and Reese) shows a typical design for a conventional oil/water separator, with slightly different features than compared to Figure F-02-1 (based upon California standards). The basic flow layout of Figure F-02-4 provides: 1) uniform tranquil flow, 2) a trash rack or other narrow opening to prevent trash and debris from flowing through, 3) a chamber for settling sediments and solids, 4) a chamber to capture floating oil and grease, and 5) access for each chamber, preferably with steps and large openings. The first two chambers for Figure F-02-4 should provide at least 400 cubic feet of permanent pool storage per acre. Both chambers must be cleaned regularly to remove floating oils and grease from the top and sediments from the bottom. Perform maintenance by using a conventional vacuum truck for both chambers, being careful not to discharge any pollutants to the stormwater outfall.

Manufactured Oil/Water Separators

A few manufacturers of oil/water separators are included in this BMP. Manufactured separators should be selected on the basis of good design, suitability for desired pollution control goals, durable materials, ease of installation, and reliability. The product list is not intended to be inclusive, nor is it intended to be an endorsement for each listed product. It is merely a list of separator manufacturers that are known to work in the Tennessee area.

Manufacturers generally provide design methods, installation guidelines, and proof of effectiveness for each application where used. These structures tend to include innovative methods of providing high-flow bypass. However, it is incumbent upon the landowner to carefully investigate the suitability and overall trustworthiness of each manufacturer and/or subcontractor.

Examples of oil/water separators illustrated in this BMP include:

Figure F-02-1	Highland Tank (CPI unit)	www.highlandtank.com
Figure F-02-5	Vortechnics, Inc.	www.vortechnics.com
Figure F-02-6	CDS Technologies	www.cdstech-us.com
Figure F-02-7	Stormceptor Corporation	www.stormceptor.com
Figure F-02-8	H.I.L. Technology, Inc.	www.hil-tech.com
Figure F-02-9	BaySaver, Inc.	www.baysaver.com

Other manufacturers include:

Aquashield, Inc.	Aqua-Swirl Concentrator	www.aquashieldinc.com
Environment 21, LLC	Ecosep	www.env21.com
StormTreat System, Inc.		www.state.ma.us/step/stepasst.htm

Each manufacturer may specify its design based upon an average design storm in order to achieve the recommended pollutant efficiency, but it is recommended that the oil/water separator should capture and treat the 1-year design storm. Other storms which are mentioned in the vendor catalogs are also the 6-month design storm (80% of the 1-year storm) and the 3-month design storm (62% of the 1-year storm).

Coalescing Plate Interceptor (CPI)

The CPI separator requires considerably less space than a conventional separator to obtain the same effluent quality. The angle of the plates to the horizontal ranges from 0° (horizontal) to 60°, with a typical plate spacing of 1 inch. Stormwater will either flow across or down through the plates. A CPI oil/water separator is able to process smaller oil droplets by collecting them upon polyurethane plates or other materials. It is recommended that the design engineer consult vendors for a plate package that will meet site and flow criteria. Manufacturers typically identify the capacity of various standard units. The angle of coalescing plates to the horizontal may range from 0° to 60°. However, at an angle of 0°, the plates would be horizontal and subject to having sediment settle on them. At an angle of 45° to 60°, sediment would be able to slide off and collect at the bottom. The spacing between plates is usually about 1 inch. Select a likely length and width of coalescing plate, and then compute number of plates needed.

Check geometry and necessary volume to contain the coalescing plates. Allow 1 foot below the plates for sediment storage. Add 6 to 12 inches above plates for oil to accumulate, and then allow an additional 1 foot above that for freeboard. Include a forebay to collect floatable debris and evenly distribute flow if more than one plate unit is needed. Larger units have a device to remove and store oil from the water surface, such as a skimmer or vacuum. Plates are easily damaged when removed for cleaning. Install plates at an angle of 45° to 60° so that most sediments slide off. Placing plates closer together reduces the total volume, but may instead allow debris such as twigs, plastics or paper to clog plates. Use a trash rack or screen to reduce clogging.

Construction/ Inspection Considerations

Install oil/water separators to manufacturer's specifications.

Maintenance

Follow vendor recommendations for manufactured oil/water separators. The following general instructions may be used in absence of conflicting data or guidelines.

- Oil/water separators should be inspected on a regular basis (such as every three months) to ensure that accumulated oil, grease, sediment, trash and floating debris do not disturb the proper functioning of the system. Record observations in an inspection log and take pictures as necessary to document conditions. Make immediate repairs as needed, and make arrangements for cleanout if needed. Consider using a licensed commercial subcontractor, who may have special equipment and abilities to perform periodic cleanout on oil/water separators.

- Perform cleanout on regular basis using confined-space procedures and equipment as required by OSHA regulations, such as nonsparking electrical equipment, oxygen meter, flammable gas meter, etc. Remove trash and debris and dispose properly. Remove floating oil, grease and petroleum substances using special vacuum hoses; treat as hazardous waste. Sediments may also contain heavy metals or other toxic substances and should be handled as hazardous waste. Removal of sediment depends on accumulation rate, available storage, watershed size, nearby construction, industrial or commercial activities upstream, etc. The sediment composition should be identified by testing prior to disposal.

- Some sediment may contain contaminants for which the Tennessee Department of Environment and Conservation (TDEC) requires special disposal procedures. Consult TDEC - Division of Water Pollution Control if uncertain about what the sediments contain or if it is known to contain contaminants. Generally, give special attention or sampling to sediments accumulated in industrial or manufacturing facilities, fueling centers or automotive maintenance areas, large parking areas, or other areas where pollutants are suspected to accumulate.

Cost Considerations

Varies, depending on manufacturer.

Limitations

- There is usually uncertainty about what types of oil or petroleum products may be encountered. A significant percentage of petroleum products are attached to fine suspended solids and therefore are not easily removed by settling.

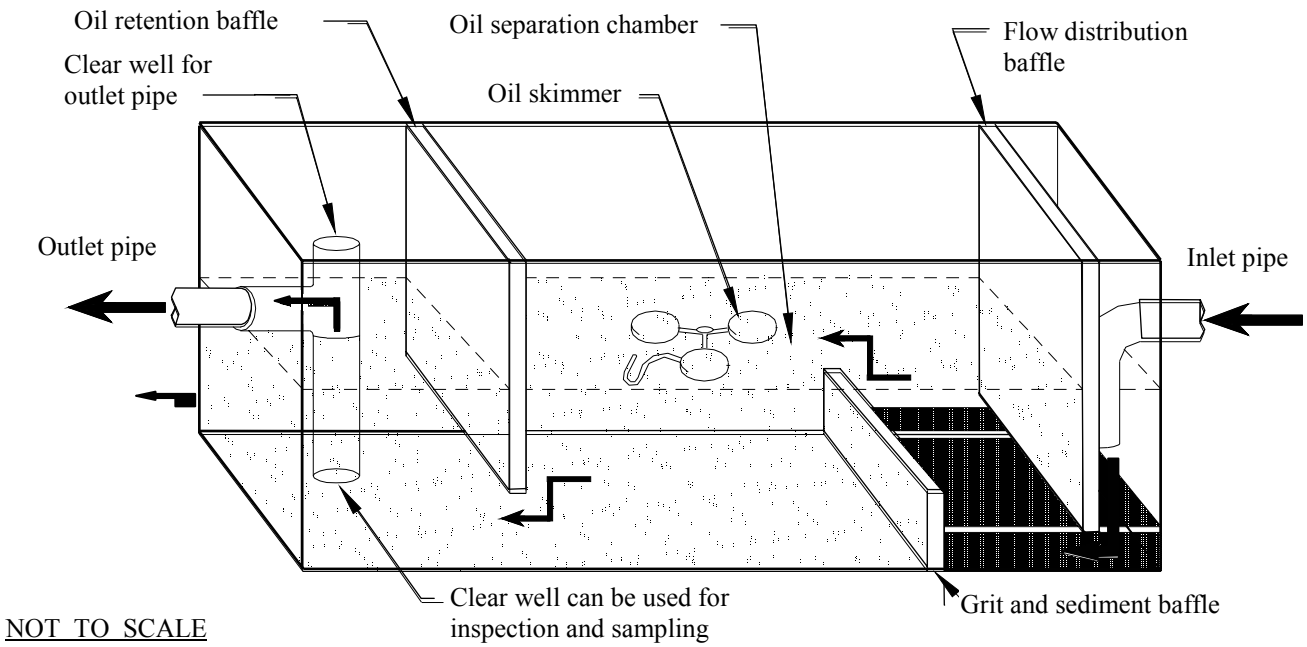
- The design loading rate for oil/water separators is low; therefore, they can only be cost-effectively sized to detain and treat nuisance and low storm flows and particularly first flush volumes. It is usually not economical or feasible to size an oil/water separator to treat a design storm with a return period longer than 1 year. Oil/water separators require frequent periodic maintenance for the life of the structure. Maintenance can be minimized (and performance can be increased) by careful planning and design, particularly upstream and downstream from separator.

- It is difficult to remove small concentrations (such as 10 ppm) from stormwater runoff which has a broad range of flows.

- The performance of oil/water separators can be difficult to estimate prior to installation and monitoring.

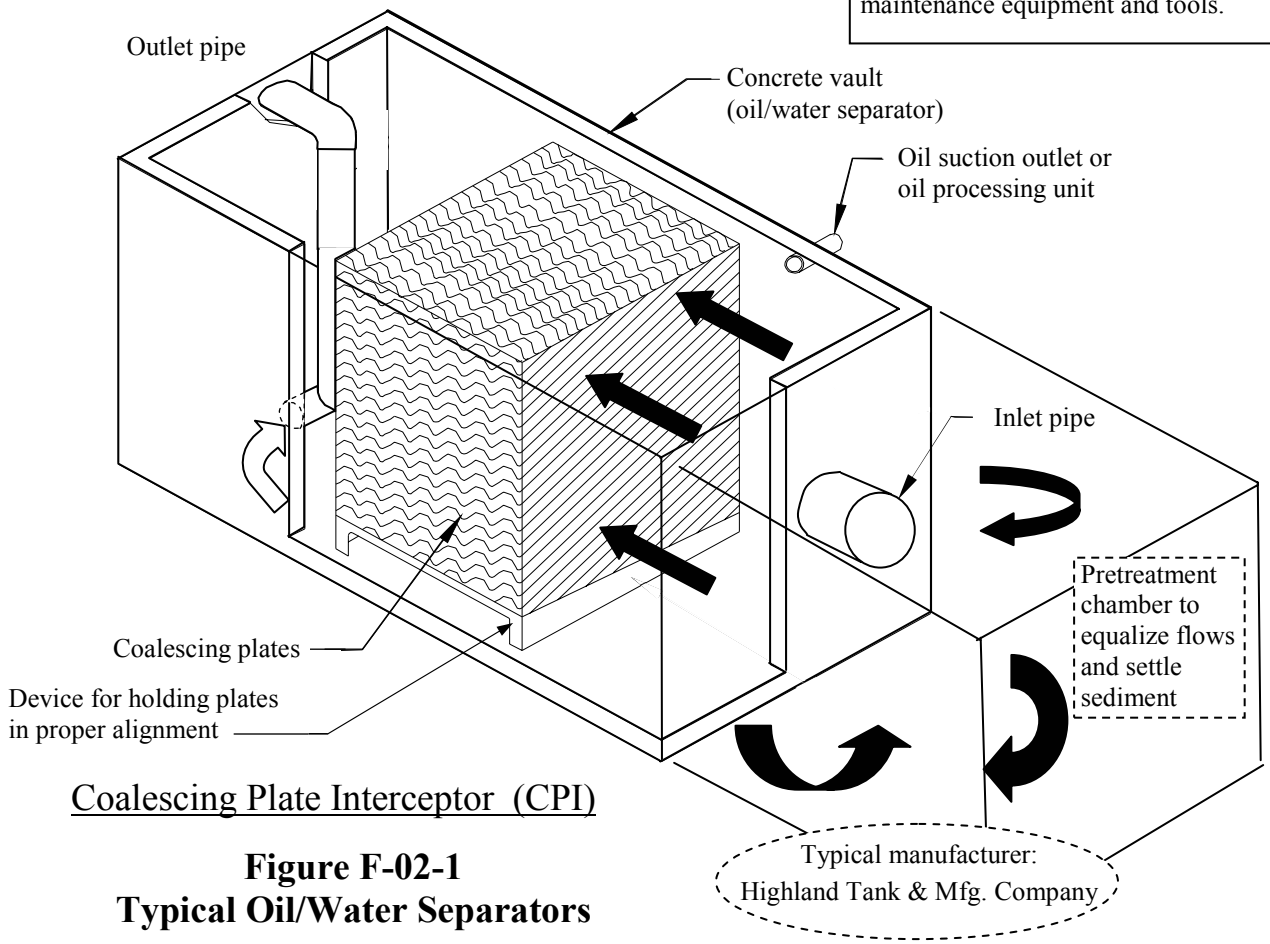
Additional Information

See attached figures.



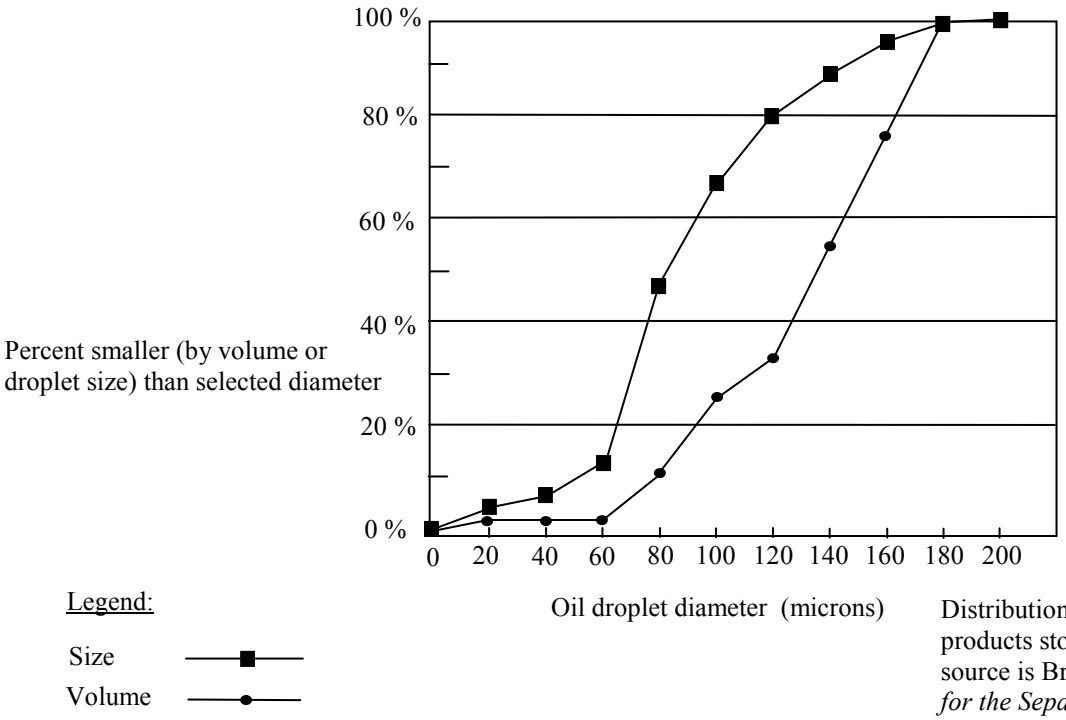
Conventional Oil/Water Separator

Provide access hatches or manhole covers for each compartment of an oil/water separator. Size openings to adequately convey all expected maintenance equipment and tools.



Coalescing Plate Interceptor (CPI)

Figure F-02-1
Typical Oil/Water Separators



Distribution for a petroleum products storage facility (original source is Branion, R., *Principles for the Separation of Oil Drops from Water in Gravity Type Separators*)

Figure F-02-2
Typical Size and Volume Distribution of Oil Droplets

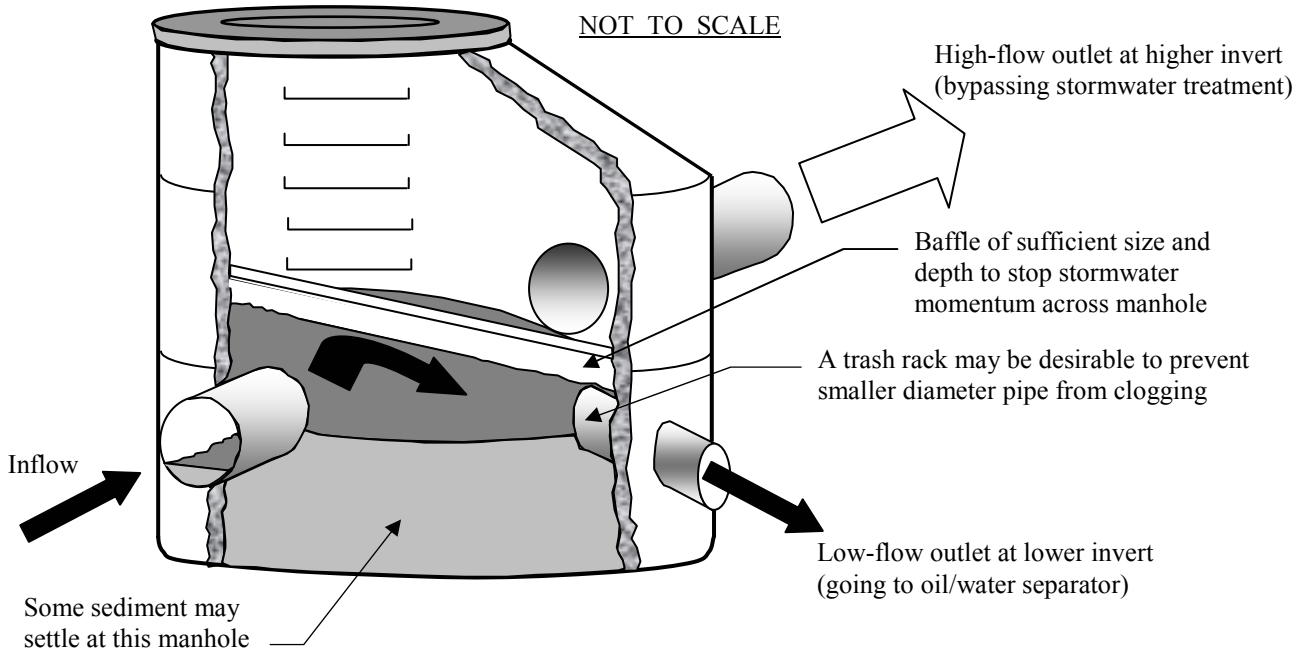
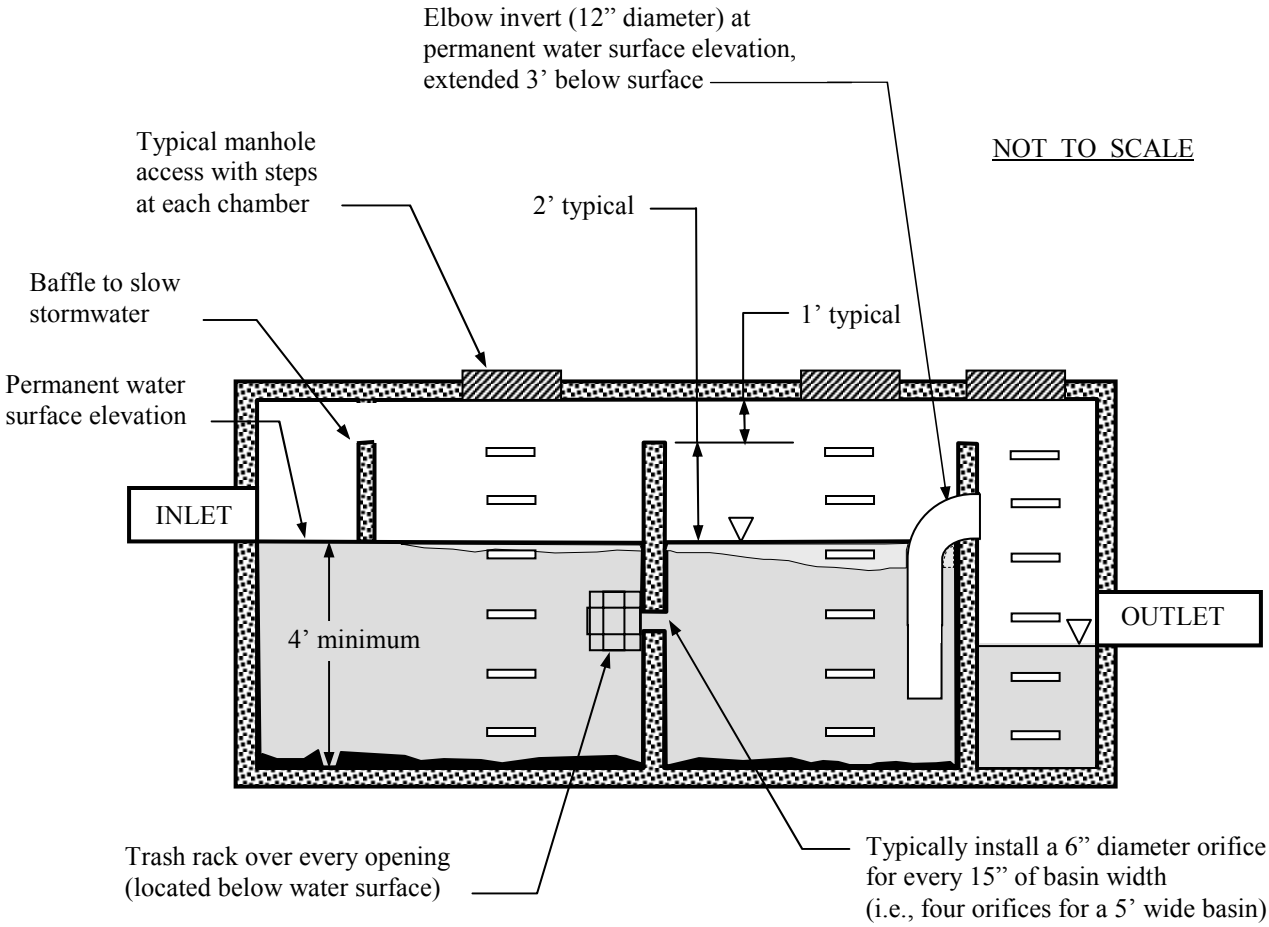


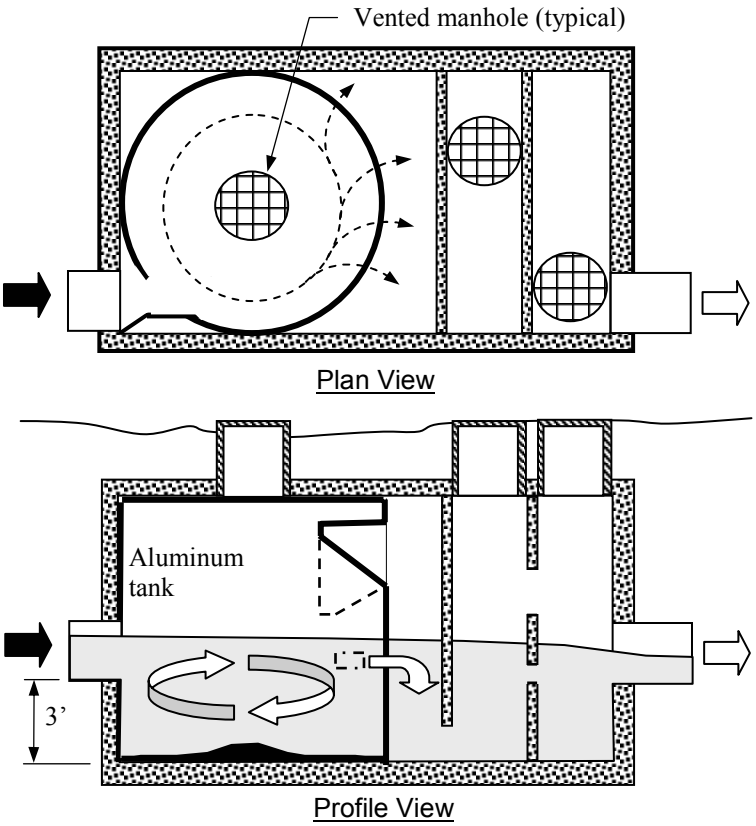
Figure F-02-3
Typical Stormwater High-Flow Bypass Manhole



Notes:

1. Provide low velocities entering the oil/water separator, and minimize opportunities for turbulence and mixing. Prevent backwater conditions downstream from the oil/water separator.
2. Minimum permanent pool storage shall be 400 cubic feet per acre of contributing drainage area.
3. Place 6" diameter orifices and 12" diameter pipe elbows across the internal walls to distribute flow evenly across the separator. Reduce or eliminate dead spots (or ineffective flow areas) in order to increase pollutant removal.
4. Label manhole lids so that the structure is easily identified as an oil/water separator. It may be necessary to control the type of truck traffic that is allowed to travel or park over a large oil/water separator.

Figure F-02-4
Conventional Oil/Water Separator

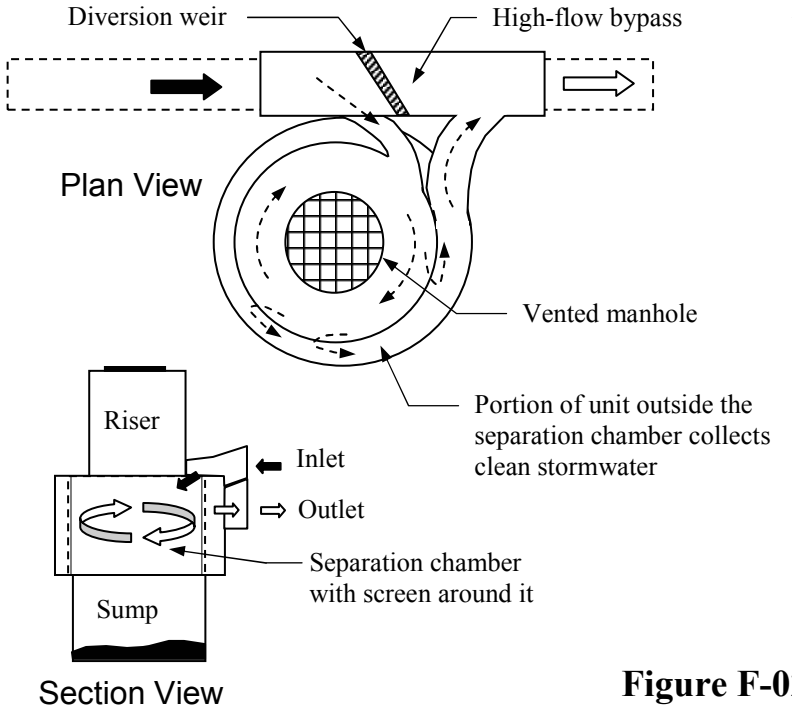


Notes:

1. This figure represents the Vortechs Stormwater Treatment Systems which uses swirl action to settle grit and sediments.
2. Vortechnics specifies a ¼" thick aluminum tank for the swirl chamber and 6" thick concrete walls for vault.
3. Inside width = tank diameter Inside length = diameter + 5' or so Inside height = 6' to 9'
4. Inlet pipe and outlet pipe may be located on side of structure. A side inlet is optimal for swirling action.
5. Use vented and labeled manhole lids so that the structure is easily identified as an oil/water separator. Vortechnics recommends minimum structural design for H-20 vehicle loading.

NOT TO SCALE

Figure F-02-5
Typical Detail for Swirl Oil/Water Separators

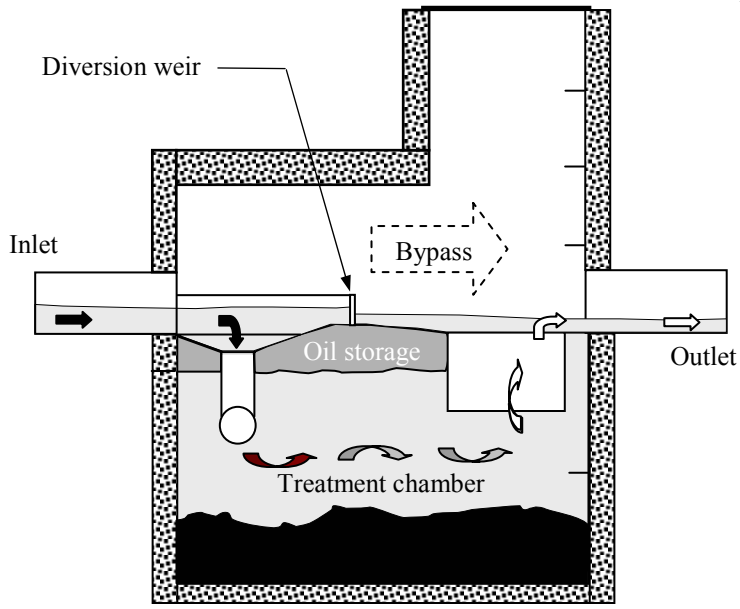


Notes:

1. This figure represents the continuous deflection stormwater treatment as manufactured by CDS Technologies. Units can also be retrofitted onto existing storm drains.
2. Units are manufactured from either fiberglass or precast concrete.
3. Manufacturer recommends the use of sorbent material within CDS separation chamber to improve capture of oil and grease. Usage rate is typically several pounds of sorbent per acre per year.

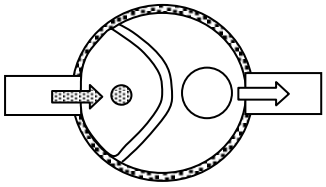
NOT TO SCALE

Figure F-02-6
Flow Schematic for Continuous Deflection Separators (CDS Technologies)



Notes:

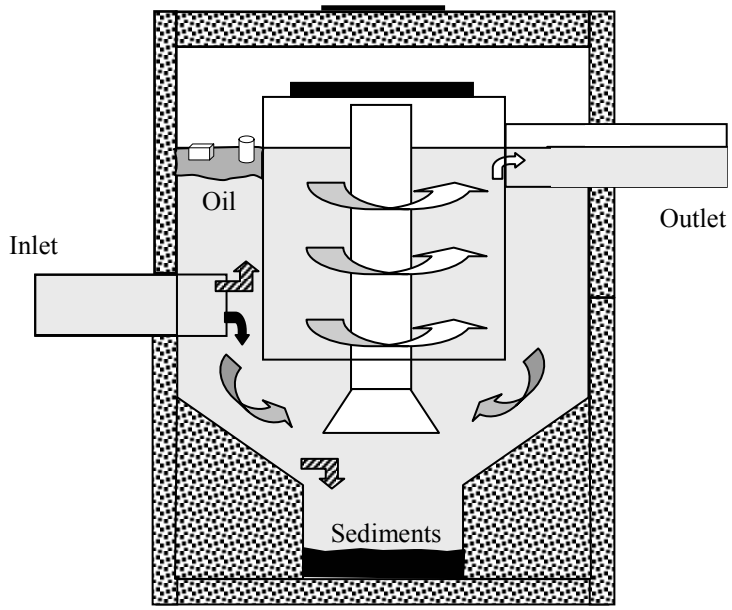
1. This figure represents a single-unit system designed to process stormwater runoff on-line, as manufactured by Stormceptor Corporation.
2. Unit consists of an insert placed into a standard concrete manhole. Basic size is 72" diameter, with larger sections used for the treatment chamber as needed.



Plan View

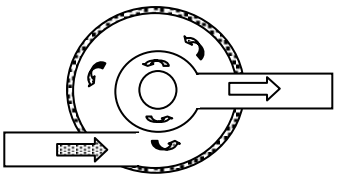
NOT TO SCALE

Figure F-02-7
Oil/Water Separator (Stormceptor)



Notes:

1. This figure shows a single unit to treat stormwater runoff, manufactured by H.I.L. Technologies, Inc.
2. Unit consists of polythelyne components supported by a stainless steel frame, inserted into a standard concrete manhole. Concrete manhole sizes vary from 4' to 10'.



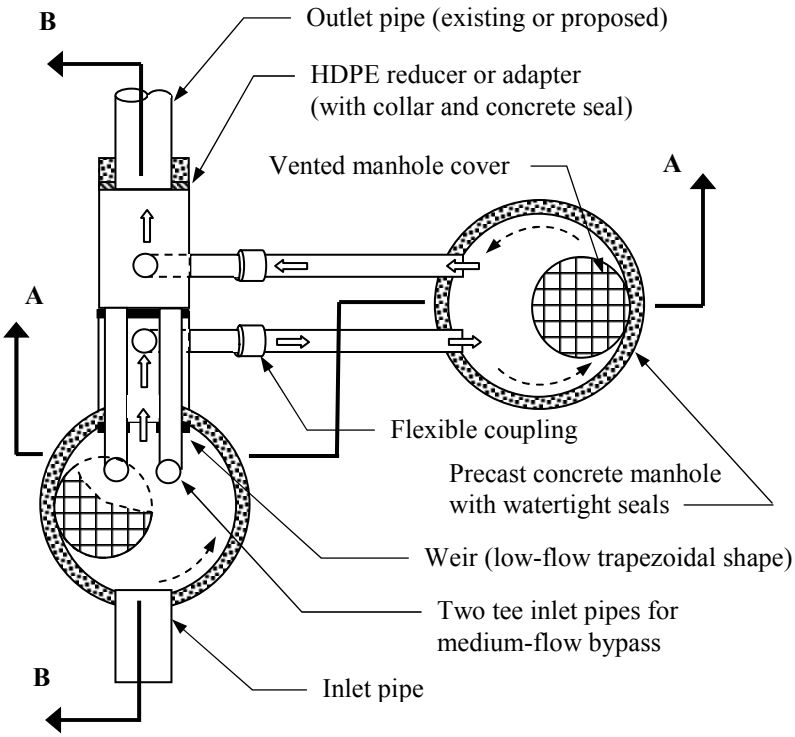
Plan View

NOT TO SCALE

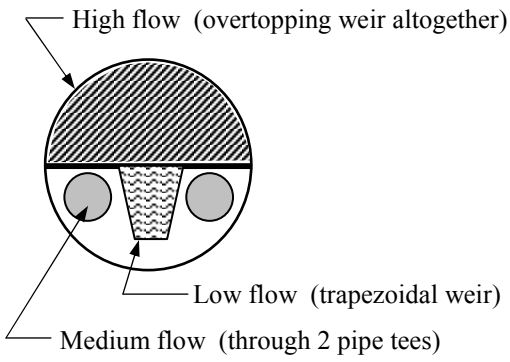
Figure F-02-8
Oil/Water Separator (Downstream Defender)

Notes:

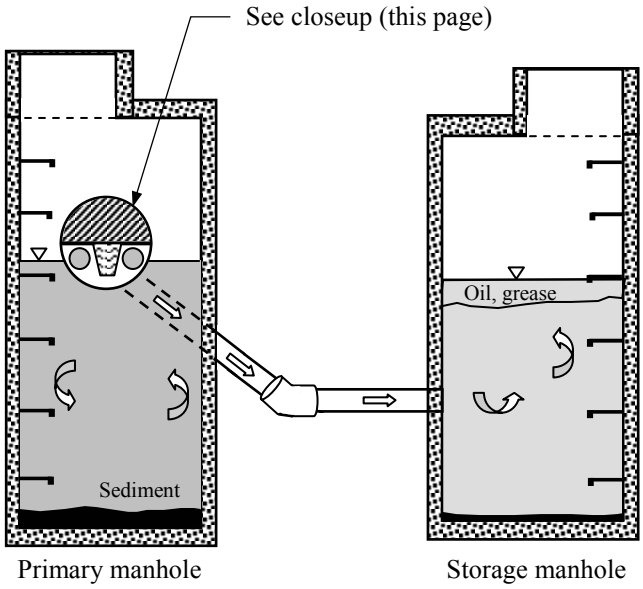
1. This figure represents the BaySaver separation system, an off-line unit that divides flows into low, medium and high regimes.
2. The unit can be retrofitted onto existing storm drain system or installed as part of a new storm drain system, using two standard precast concrete manholes.



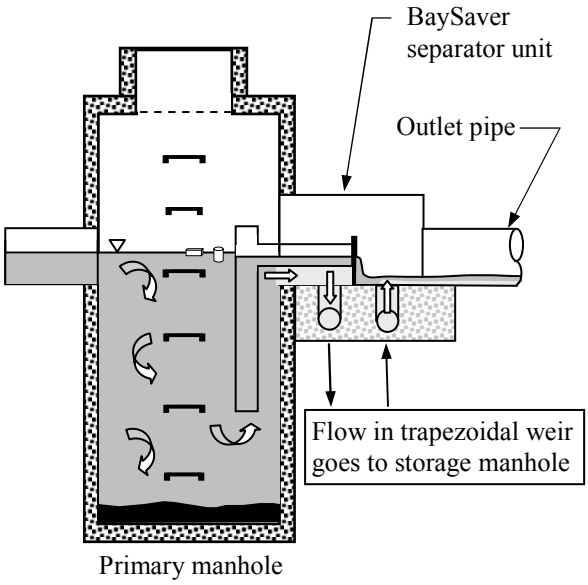
Plan View (with low flow)



Closeup of Section A-A (flow control)



Section A-A (with low flow)



Section B-B (with medium flow)

NOT TO SCALE

Figure F-02-9
Flow Schematic for Dual Tank System

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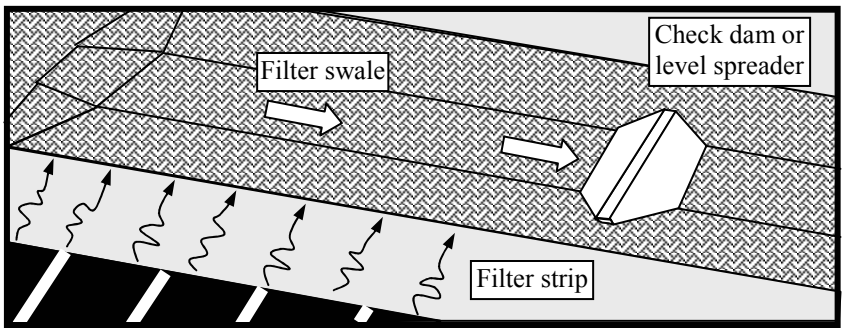
Vendor Data

ACTIVITY: Filter and Buffer Strips

F – 03



Targeted Constituents				
● Significant Benefit		◗ Partial Benefit		○ Low or Unknown Benefit
◗ Sediment	◗ Heavy Metals	○ Floatable Materials	◗ Oxygen Demanding Substances	
◗ Nutrients	◗ Toxic Materials	◗ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes
Implementation Requirements				
● High		◗ Medium		○ Low
◗ Capital Costs	◗ O & M Costs	◗ Maintenance		○ Training

Description

Filter and buffer strips are able to remove some sediments and pollutants from stormwater runoff if correctly designed and constructed. Low velocities, combined with healthy stands of grass vegetation, allow particles and debris to settle and filter out from stormwater runoff. These strips can be composed of grass or forest buffer zones, provided that efforts are made to ensure sheet flow to the buffer zone. Generally, a maintained grass filter strip is used to treat very shallow, or sheet flow. Filter strips are often used as pretreatment for other BMPs. This practice will provide a partial reduction in most types of pollutants, and will provide some groundwater recharge.

Selection Criteria

- Filter and buffer strips are often used in conjunction with other stormwater management practices to treat runoff from paved streets and parking lots.
- Filter and buffer strips can also be used to reduce the amount of directly connected impervious area (DCIA) that drains into the storm drainage system, thus reducing peak flows. In addition to pavement areas, this typically can be used for rooftops.

Design and Sizing Considerations

A filter strip is a relatively flat area (recommended 5 percent maximum grade) of healthy grass vegetation adjacent to or downstream from an impervious surface that may contain pollutants. A wildgrass or forest buffer zone may function as a filter strip. A filter strip is usually intended for sheet flow from small parking lots or streets and low-density residential and agricultural areas. A level spreader may be required to convert concentrated (channel) flow into sheet flow. Filter and buffer strips are not recommended to treat catchments larger than 5 acres.

Filter and buffer strips perform well for small light-intensity rainfalls, but typically have no effect on the large design rainfalls used for stormwater detention. Since most precipitation occurs during light-intensity rainfalls, filter and buffer strips are a major component in improving water quality from sheetflow runoff. Detention basins and constructed wetlands are relied upon to provide water quality treatment both during and between storms for the large design rainfalls. Filter and buffer strips should

generally be used in combination with other stormwater treatment BMPs whenever possible.

Poor maintenance techniques, "short -circuiting", poor vegetative cover, and unsuitable location are several causes of filter strip failure. Filter strips have relatively high failure rates.

Figure F-03-2 shows examples of how filter strips can be used in parking lots and residential properties. Since thick and healthy grass vegetation is a part of most landscaped properties, filter and buffer strips are easy to incorporate into most BMP strategies. Filter and buffer strips have removed as much as 80% of total suspended sediments and 50% of soluble zinc in the metropolitan Washington D.C. area if properly constructed, but have not shown any removal for dissolved phosphorous or copper (Metropolitan Washington Council of Governments, 1992). Other studies have also shown little or no removal for heavy metals, and also generally poor performance due to incorrect construction. California guidelines include a typical size for filter strips equal to 1000 square feet per impervious acre, with a minimum width of 10 feet (Camp Dresser & McKee, et al, 1993).

The upper layout (Figure 2A - parking lot) shows sheet flow entering a wide swale rather than a gutter or curb inlet. Design considerations include width of swale, the anticipated overhang of vehicles, whether to use wheel stops, and spacing of grate inlets. In general, the grate inlets should flow to a detention basin or other stormwater treatment BMP prior to being discharged to a storm drainage system or natural stream.

The lower layout (Figure 2B – residential property) shows impervious area from rooftops and driveways. Rooftop drainage typically reaches ground level via gutters and downspouts, and it is understood that this stormwater should be conveyed at least 5 to 10 feet from the building to avoid wet basements or saturated foundations. However, downspouts should be turned into sheet flow through filter strips whenever possible.

To force ponding in a vegetated filter strip, a pervious berm constructed of a moderately permeable soil may be installed. An armored overflow should be provided in order to aid in the bypass of larger storms.

Filter and buffer strips and swales may also be used as a temporary erosion control strategy, in conjunction with other erosion control measures. Filter strips are applicable on construction sites to reduce sediment damage to adjacent properties and to disconnect upstream developments from receiving waterbodies. Filter and buffer strips and swales are used downstream from erosion control measures that remove most coarse sediment and silts from the stormwater. Also, sod (if properly pegged and stabilized) may be used as part of temporary inlet protection in conjunction with silt fence or straw bale barriers. Downstream bank erosion can be prevented by filter strips.

Habitats for wildlife, some water quality improvements, aesthetics, and occasional recreation are all benefits of a properly designed and maintained filter strip.

Pollutant Removal Efficiency

Pollutant Removal Capability: Filter strips are capable of removing suspended solids,

nutrients, and organics as long as the flow is low to moderate (Schueler et al, 1987). Infiltration and biological uptake also occur as runoff flows through the filter strip. Removal capabilities are a function of the geometry of the filter strip and the contributing watershed area.

Total suspended solid removal efficiency for grass filter strips and grass buffers can be estimated using Figure F-03-1. Compute travel time using typical SCS methods such as the kinematic equation for time of concentration. Then enter the graph with an assumed depth of 0.02 feet (or about 0.25 inches). The effectiveness of a grass filter strip depends heavily upon sheet flow being maintained across the grass surface. This is accomplished by level spreaders and by careful maintenance of the grass surface.

Other design criteria are as follows:

- Forested filter strips have a high capability for pollutant removal due to biological uptake and longer retention in the forested areas; however, without the vegetative cover of grassed covered strips, forested strips should be at least two times as long as grassed filter strips.
- Wide filter strips help to maintain sheetlflow.
- The lowest elevation in the filter strip should be at least two feet above the water table.
- Keep flow paths to the strip less than 150 feet to prevent shallow concentrated flows.
- Organic matter surfaces and clay soils improve the nutrient removal capability of filter strips (Schueler et al, 1992). An infiltration rate of 0.52 inches per hour is recommended, such as a sandy loam (VDCR, 1999). Soils should be capable of sustaining vegetation with minimal fertilization.
- The water table should at least two feet below the surface to help increase the removal of soluble pollutants through infiltration (VDCR, 1999).
- Filter strips do not function properly during high flows. High velocities can cause the runoff to channelize and prevent pollutant removal. The maximum flow velocity allowed is 0.5 feet per second (KCDNR, 1998).
- The depth of flow on the filter strip should not exceed the height of the grass. A good rule of thumb is a maximum of 1.0 inch (KCDNR, 1998).
- Ultra-urban areas tend to have large amounts of impervious areas and subsequently, high runoff velocities. Because of the inability of filter strips to function properly under high flows, they are not recommended in such areas.
- Filter strips are not capable of attenuating peak flows, but instead can help to decrease runoff velocities and time of concentration. They are mostly used for water quality purposes and are most effective when used in conjunction with other BMPs.

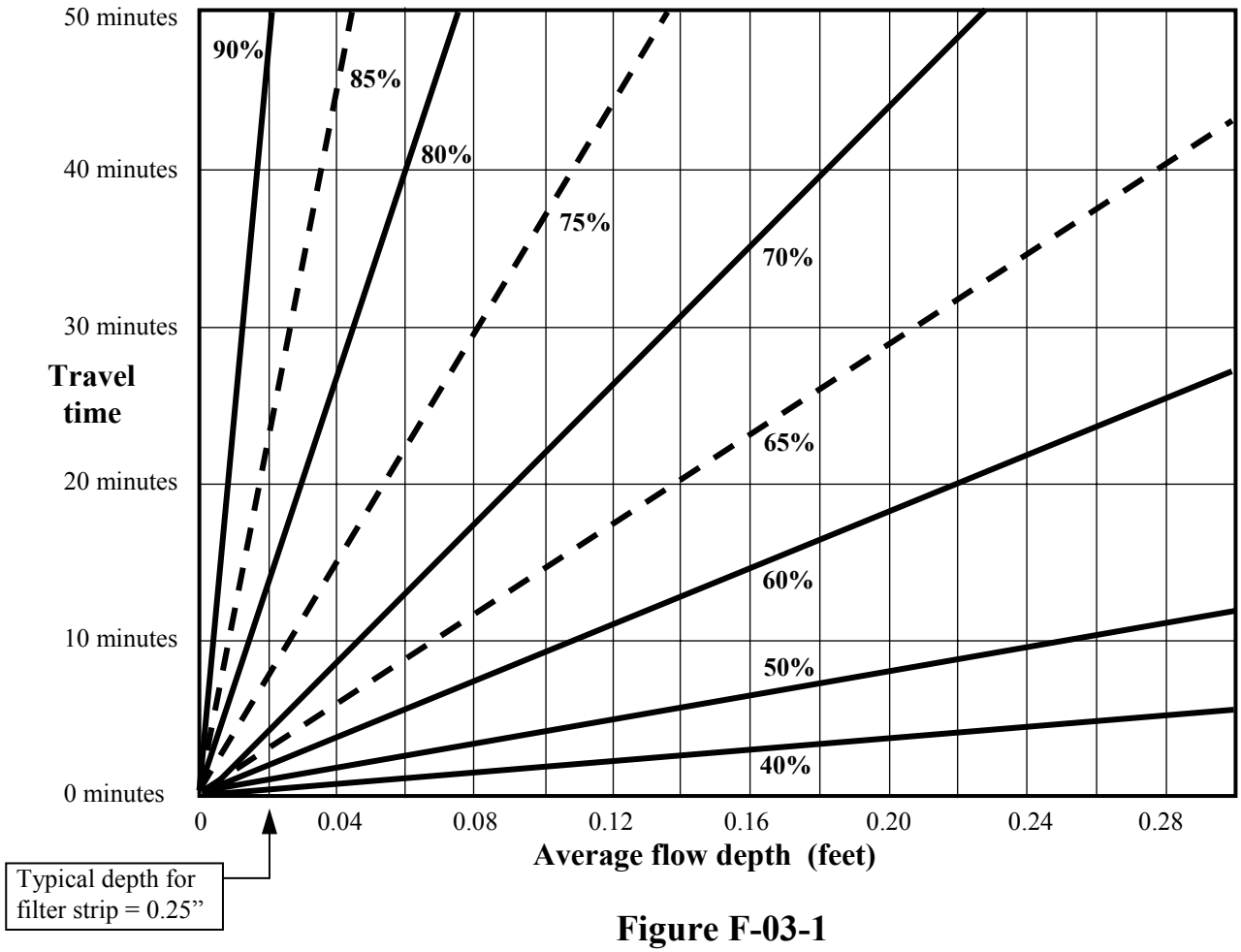


Figure F-03-1
TSS Removal Efficiency for Grass Swales and Filters

Construction/ Inspection Considerations

A minimum width of 10 feet is recommended for vegetated filter strips at a slope of 1%. Widths of 20 to 30 feet are highly recommended, particularly if the slope is more than 1%. The length of a filter strip is typically the entire length of the adjacent parking lot, street, or building. The use of sod is very beneficial in establishing a filter strip, particularly for small widths such as 10 feet. Limit the width of pavement that drains to a filter strip; typical values should be 50 to 100 feet whenever possible. Since curbs and curb cuts will concentrate flows, curbs and gutters are not desirable for

paved areas with filter strips. Avoid concentrating stormwater runoff on pavements by ensuring that the pavement slopes and vegetated surface slopes are level or change very gradually. In busy parking lots, vehicle wheels or parking curb stops may channelize flow in some instances. Channelization will reduce the effective treatment area of the filter strip and may erode grass because of excessive velocities. A level spreader, check dam or energy dissipater may assist in returning channelized flow back into sheet flow, if designed and constructed properly.

Protect grass filter strips from vehicle traffic; this is typically done with wheel stops made of precast concrete, iron or landscaping timbers. Even heavy foot traffic can compact the topsoil and trample the grass, affecting performance of a filter strip. Design and analyze probable areas of foot traffic, and provide paths and sidewalks that are compatible with the grass filter strips. If irregular or uneven areas appear while the vegetation is being established, repair and restore to a smooth and even appearance to prevent concentrating stormwater sheet flows.

Sod Placement

Sodded grass is preferable to seeded grass vegetation, but either method may be used to establish grass filter strips. Sod has the advantages of immediate erosion control and stormwater treatment, healthier stands of vegetation, aesthetics, less maintenance and less inspection, and increased property values. Refer to Figure F-03-3 for a relative comparison of various types of turfgrass; information is also available from the UT Agricultural Extension website.

Sod guidelines are explained more fully in the *Tennessee Erosion and Sediment Control Handbook*. Protect sod with tarps or other covers during delivery so that it does not dry out between harvesting and placement. Prepare subgrade by removing all weeds and debris, then add fertilizer, lime and water as needed. Place sod in staggered fashion so that there are no long seams. After placing sod, lightly roll to eliminate air pockets and ensure close contact with the soil. After rolling, the sodded areas shall be watered so that the soil is moistened to a minimum depth of 4 inches. Sod should not be planted during very hot or wet weather. Do not place sod on slopes that are greater than 3:1 (H:V) if they are to be mowed.

Maintenance

- Filter and buffer strips should be inspected regularly during the establishment of vegetation. Repair or replace any damage to the sod, vegetation, or evenness of grade as needed. Look for signs of erosion, distressed vegetation or channelization of sheet flow.
- In general, grass vegetation should not be mowed shorter than 3 inches. Maximum recommended length of grass is 6 to 8 inches. Allowing the grass to grow taller may cause it to thin and become less effective. The clippings should be bagged and removed. Mowing grass regularly promotes growth and pollutant uptake.
- Keep all level spreaders or check dams even and free of debris. Remove all debris and sediment by hand and with a flat-bottomed shovel during dry periods, leaving as much of the vegetation in place as possible. Reseed or plug any damaged turf or vegetation.
- Rake or remove trapped trash such as cigarette butts and other debris to ensure a healthy filtering quality.

- Areas disturbed during construction should be immediately reseeded for proper vegetative cover.
- If the filter strip was used as a sediment control measure during construction, it should be reseeded and regraded immediately afterwards so that flow patterns within the strip are not altered.
- Proper maintenance of the filter strip, including spot repairs, fertilization, and maintaining the top edge of the filter to prevent channelization are very important, as are periodic inspections.

Sediment Removal

- The sediment accumulation rate is dependent on a number of factors such as land use, watershed size, types of industry, nearby construction, etc. The sediment composition should be identified before being removed and disposed.
- Periodic sediment removal will help maintain the infiltration and uptake capacity of the filter strip and help keep the original terrain of the area by preventing soil build-up.
- Some sediment may contain contaminants for which the Tennessee Department of Environment and Conservation (TDEC) requires special disposal procedures. Consult TDEC - Division of Water Pollution Control if there is any uncertainty about what the sediment contains or if it is known to contain contaminants. Generally, special attention or sampling should be given to sediments accumulated in facilities serving industrial, manufacturing or heavy commercial sites, fueling centers or automotive maintenance areas, large parking areas, or other areas where pollutants are suspected to accumulate.
- Clean sediment can be used as fill material, hole filling, or land spreading. It is important that this material not be placed in a way that will promote or allow resuspension in storm runoff.

Cost Considerations

The cost of constructing a filter strip is very low, especially reduced if constructed before development of the surrounding area. According to an EPA website (1993), an average filter strip will cost approximately $85.41 per acre, in 1990 dollars.

Limitations

- Grass filter strips can only treat sheet flow. Curb cuts have the effect of channelizing sheet flow and are not useful in establishing grass filter strips as a stormwater treatment BMP.
- Grass filter and buffer strips are effective only on gentle slopes, typically less than 1 or 2 percent. Filter and buffer strips located on steeper slopes generally will not receive credit as being a stormwater treatment BMP. Site topography may not allow the use of grass filter and buffer strips
- Grass filter and buffer strips are useful primarily for small areas only, typically 1 acre or less. Larger project sites or properties can also make effective use of filter and buffer strips for smaller subbasins.
- Proper maintenance is required to maintain the health and density of grass vegetation, such as irrigation during summer droughts and adding small amounts

of fertilizer or lime as needed.

- Filter strips are not recommended in areas with high runoff velocities and therefore should not be constructed in highly urbanized, impervious areas.
- Filter strips pose little threat to the environment, other than a slight risk to groundwater contamination.

Additional Information

Examples of filtering systems and grass characteristics are provided below.

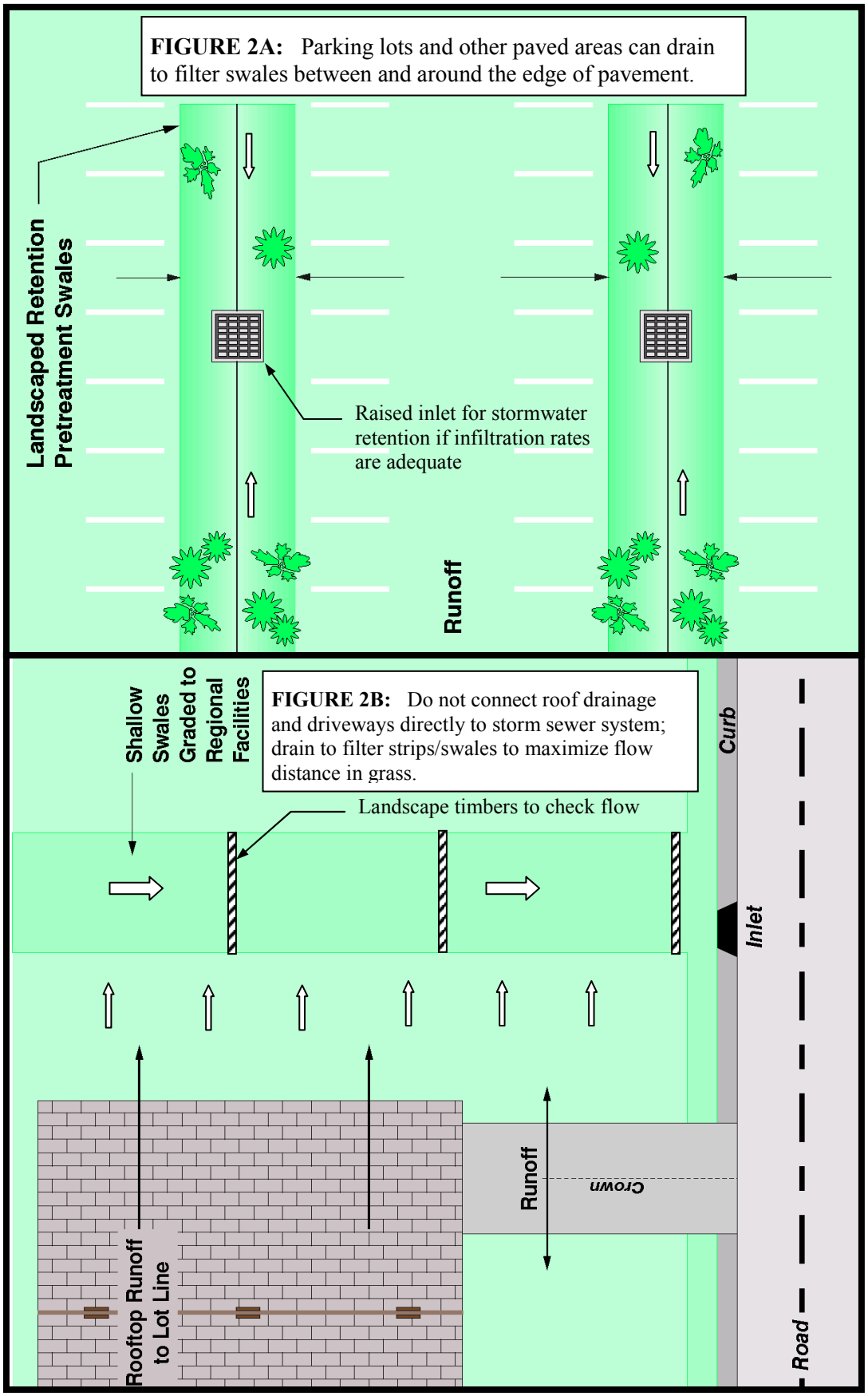


Figure F-03-2
Examples of Filter Strips and Swales

COLD TOLERANCE (winter color persistance)

High
- Creeping bentgrass
- Kentucky bluegrass
- Red fescue
- Colonial bentgrass
- Highland bentgrass
- Perennial ryegrass
- Tall fescue
- Weeping alkaligrass
- Dichondra
- Zoysiagrass
- Common bermudagrass
- Hybrid bermudagrass
- Kikuyugrass
- Seashore paspalum
- St. Augustinegrass

Low

HEAT TOLERANCE

High
- Zoysiagrass
- Hybrid bermudagrass
- Common bermudagrass
- Seashore paspalum
- St. Augustinegrass
- Kikuyugrass
- Tall fescue
- Dichondra
- Creeping bentgrass
- Kentucky bluegrass
- Highland bentgrass
- Perennial ryegrass
- Colonial bentgrass
- Weeping alkaligrass
- Red fescue

Low

MOWING HEIGHT ADAPTATION

High cut
- Tall fescue
- Red fescue
- Kentucky bluegrass
- Perennial ryegrass
- Weeping alkaligrass
- St. Augustinegrass
- Common bermudagrass
- Dichondra
- Kikuyugrass
- Colonial bentgrass
- Highland bentgrass
- Zoysiagrass
- Seashore paspalum
- Hybrid bermudagrass
- Creeping bentgrass

Low Cut

DROUGHT TOLERANCE

High
- Hybrid bermudagrass
- Zoysiagrass
- Common bermudagrass
- Seashore paspalum
- St. Augustinegrass
- Kikuyugrass
- Tall fescue
- Red fescue
- Kentucky bluegrass
- Perennial ryegrass
- Highland bentgrass
- Creeping bentgrass
- Colonial bentgrass
- Weeping alkaligrass
- Dichondra

Low

MAINTENANCE COST AND EFFORT

High
- Creeping bentgrass
- Dichondra
- Hybrid bermudagrass
- Kentucky bluegrass
- Colonial bentgrass
- Seashore paspalum
- Perennial ryegrass
- St. Augustinegrass
- Highland bentgrass
- Zoysiagrass
- Tall fescue
- Common bermudagrass
- Kikuyugrass

Low

Taken from California Cooperative Agricultural Extension (1984)

Figure F-03-3
Characteristics of Various Types of Grass

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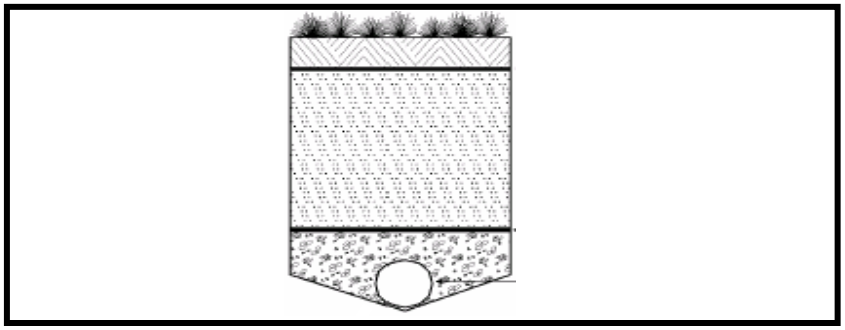
ACTIVITY: Filter / Adsorption Bed

F – 04



Targeted Constituents				
● Significant Benefit		◗ Partial Benefit		○ Low or Unknown Benefit
◗ Sediment	◗ Heavy Metals	○ Floatable Materials	◗ Oxygen Demanding Substances	
◗ Nutrients	◗ Toxic Materials	◗ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes

Implementation Requirements			
● High		◗ Medium	○ Low
● Capital Costs	● O & M Costs	◗ Maintenance	○ Training

Description

The filter, or adsorption, bed is a ground-level open-air structure that can capture and temporarily store stormwater runoff and filter it through a bed of sand. It is capable of treating drainage areas up to 10 acres in size and is typically located off-line. Filter beds can be designed as an excavation with an earthen embankment or as a concrete structure.

Most sand filter systems consist of two-chamber structures. The first chamber is a sediment forebay, which removes debris and heavy sediments, while the second chamber, or filtration chamber, removes additional pollutants by filtering the runoff through a sand bed. The filtered runoff is typically collected and returned to the conveyance system or exfiltrated into the surrounding soil.

Selection Criteria

Because they have few site constraints beside head requirements, filter beds can be used on development sites where the use of other structural controls may be used. However, sand filter systems can be relatively expensive to construct and install.

Sand filter systems are designed primarily as off-line systems for stormwater quality (i.e., the removal of stormwater pollutants) and will typically need to be used in conjunction with another structural control to provide downstream channel protection, overbank flood protection, and extreme flood protection, if required. However, under certain circumstances, filters can provide limited runoff quantity control, particularly for smaller storm events.

Sand filter systems are well suited for highly impervious areas where land available for structural controls is limited. Sand filters should primarily be considered for new construction or retrofit opportunities for commercial, industrial, and institutional areas where the sediment load is relatively low, such as: parking lots, driveways, loading docks, gas stations, garages, airport runways/taxiways, and storage yards. Sand filters may also be feasible and appropriate in some multi-family or higher density residential developments.

To avoid rapid clogging and failure of the filter media, the use of sand filters should be avoided in areas with less than 50% impervious cover, or high sediment yield sites

with clay/silt soils. The following basic criteria should be evaluated to ensure the suitability of a sand filter facility for meeting stormwater management objectives on a site or development.

Design and Sizing Considerations

Some factors to consider in design are included below:

- Maximum contributing drainage area to an individual stormwater filtering system should be less than 10 acres.
- Pretreatment measures such as filter strips are required to prevent sediment, oil, and grease from clogging the filter.
- Most sand filters normally require one to six feet of head.
- Sand filter systems are designed for intermittent flow and must be allowed to drain completely in 48 hours and re-aerate between rainfall events. They should not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.
- Inlet structure should be designed to spread the flow uniformly across the surface of the filter media.
- An emergency overflow structure should be included in design to bypass larger storms. See P-01, Detention Ponds, for more information.
- Stone riprap or other dissipation devices should be installed to prevent gouging of the sand media and to promote uniform flow.
- Underdrain pipes should consist of main collector pipes and perforated lateral branch pipes.
- The underdrain piping should be designed or reinforced to withstand the weight of the overburden.
- Internal diameters of lateral branch pipes should be 4 inches or greater (6 inches preferred) and perforations should be 3/8 inch. Maximum spacing between rows of perforations should not exceed 6 inches.
- All piping should be schedule 40 polyvinyl chloride or greater strength.
- Maximum grade across filter should be 6%.
- Minimum grade of piping should be 1%.
- At least two feet are required between the bottom of the sand filter and the elevation of the seasonally high water table.
- Access for cleaning all underdrain piping should be provided.
- Surface filters may have a grass cover to aid in pollution adsorption.
- Sand/peat beds have higher removal effectiveness due to adsorptive properties of peat.

Two sand bed configurations are recommended for use. A typical sand media cross section is shown as Figure F-04-2.

Sand Bed with Gravel Layer

- Top layer of sand should be a minimum of 18 inches of 0.02 - 0.04 inch diameter sand (smaller sand size is acceptable).
- A layer of one-half to 2-inch diameter gravel under the sand should be provided for a minimum of 2 inches of cover over the top of the under-drain lateral pipes.
- No gravel is required under the lateral pipes.
- A layer of geotextile fabric (permeable filter fabric) should separate the sand and gravel.

Sand Bed with Trench

- Top layer of sand is to be 12-18 inches of 0.02 - 0.04 inch diameter sand (smaller size is acceptable).
- Laterals to be placed in trenches with a covering of one-half to 2-inch gravel and geotextile fabric.
- The lateral pipes are to be underlain by a layer of drainage matting.
- A presettling basin and/or biofiltration swale is recommended to pretreat runoff discharging to the sand filter.
- A maximum spacing of 10 feet between lateral underdrain pipes is recommended.

Construction/ Inspection Considerations

Some construction considerations are as follows:

- Heavy construction equipment, vehicles, and even excessive foot travel can compact the filter media and reduce its effectiveness.
- Filter beds will not function properly if clogged with sediment and debris, and therefore most of the designs are not recommended near construction areas without appropriate sediment control.
- Vegetation should be established over the contributing drainage areas before runoff can be accepted into the facility.

Maintenance

Some maintenance guidelines to consider are below:

- Inspect filter beds on a regular basis, typically every month and after heavy rainfalls. Record observations in an inspection log and take pictures as necessary to document conditions. Make immediate repairs as needed. Clean or replace filtration media as needed to prevent clogging.
- Remove trash, debris, sediments or clogged media as needed, and then dispose of them properly. Sediments or clogged media may contain heavy metals or other toxic substances and should be handled as hazardous waste. Removal of sediment or clogged media depends on the accumulation rate, available storage, watershed size, nearby construction, industrial or commercial activities upstream, etc. Sediment or clogged media should be tested for identification of pollutants prior to disposal.
- Some sediment may contain contaminants for which the Tennessee Department of Environment and Conservation (TDEC) requires special disposal procedures.

Consult TDEC - Division of Water Pollution Control if uncertain about what the sediments contain or if it is known to contain contaminants. Generally, give special attention or sampling to sediments accumulated in industrial or manufacturing facilities, fueling centers or automotive maintenance areas, large parking areas, or other areas where pollutants are suspected to accumulate.

- Scrape off sediment layer buildup during dry periods with steel rakes or other devices.
- Replace some or all of the sand when permeability of the filter media is reduced to unacceptable levels, which should be specified in the design of the facility. When the bed does not completely drain within 48 hours of the end of a rainfall, the top layers of media (topsoil and 2 to 3 inches of sand) should be removed and replaced.
- It is generally more cost efficient to clean the filtration media than to replace it. For sand filters, cleaning or replacement of the top few inches may restore the permeability rate. Failure to clean the filter surface regularly may result in the need to replace the entire media because of penetration of fines into the filter.
- A very important consideration is the allocation of long-term resources for inspection, maintenance and repair.
- It is important to keep the filters clean. Any debris, sediment, grass clippings, etc. should be removed from the system and properly disposed.

Cost Considerations

Capital costs and maintenance can be relatively expensive for this type of BMP.

Limitations

Some limitations of filter beds are as follows:

- Filter beds will require more frequent inspection and maintenance than most other stormwater treatment BMPs. Filtration media will need to be cleaned and/or replaced frequently. There is very high potential for severe clogging or reduced pollutant removal efficiency in filtration systems, particularly if there are unstabilized soil surfaces upstream. Do not operate filtration systems until upstream erosion areas are controlled.
- Media filtration systems cause a large head loss that may require special consideration in the hydraulic design of the overall stormwater collection system. Systems may typically require vertical filtration through at least 18 inches of sand and underdrain material.
- There is a possibility of pulse loadings due to resuspension of pollutants from dirty filters during intense storms.
- It is difficult to dispose of spent filter media in methods that are environmentally sound and cost-effective.

Additional Information

See attached figures.

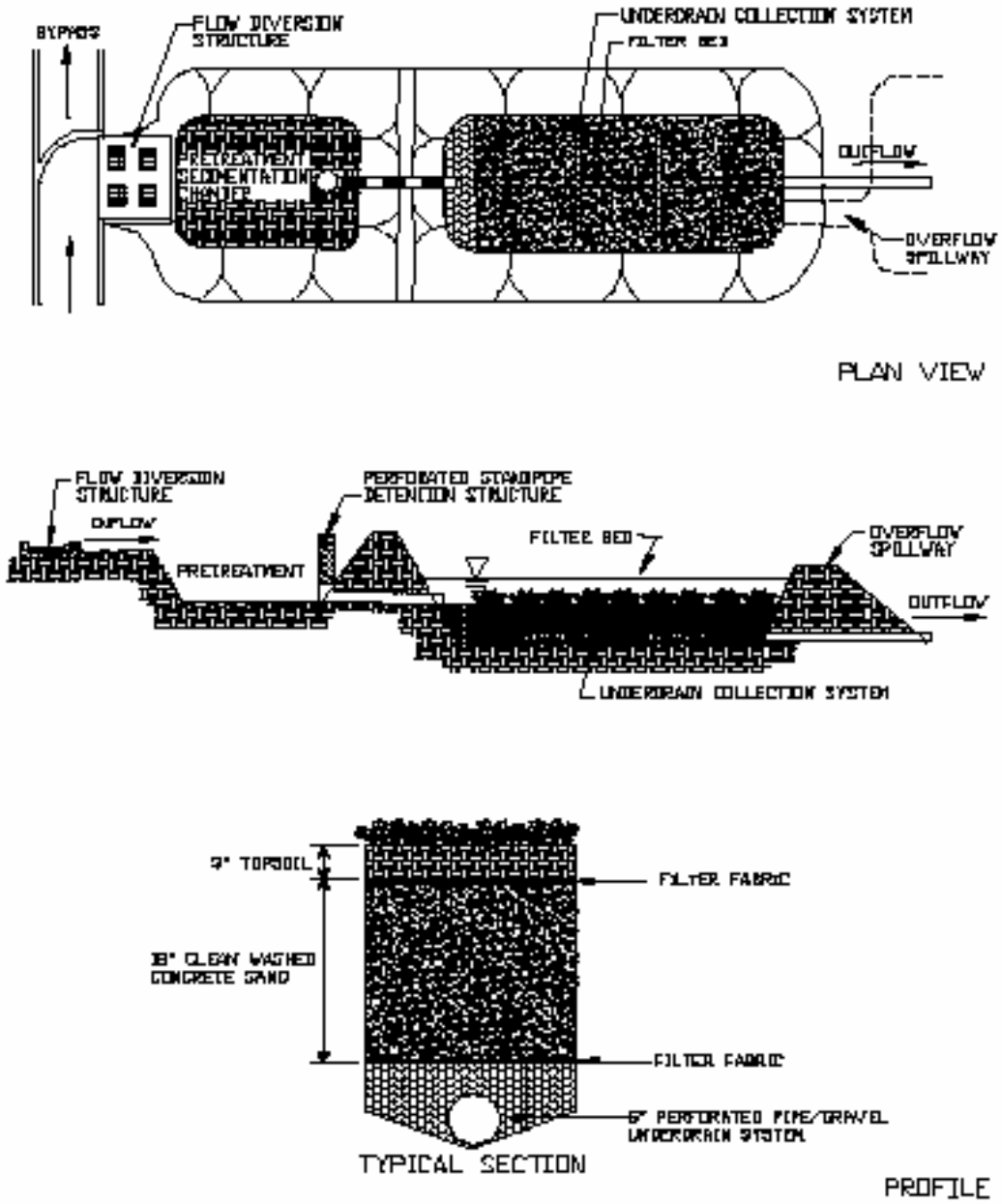


Figure F-04-1
Typical Filter Bed Layout

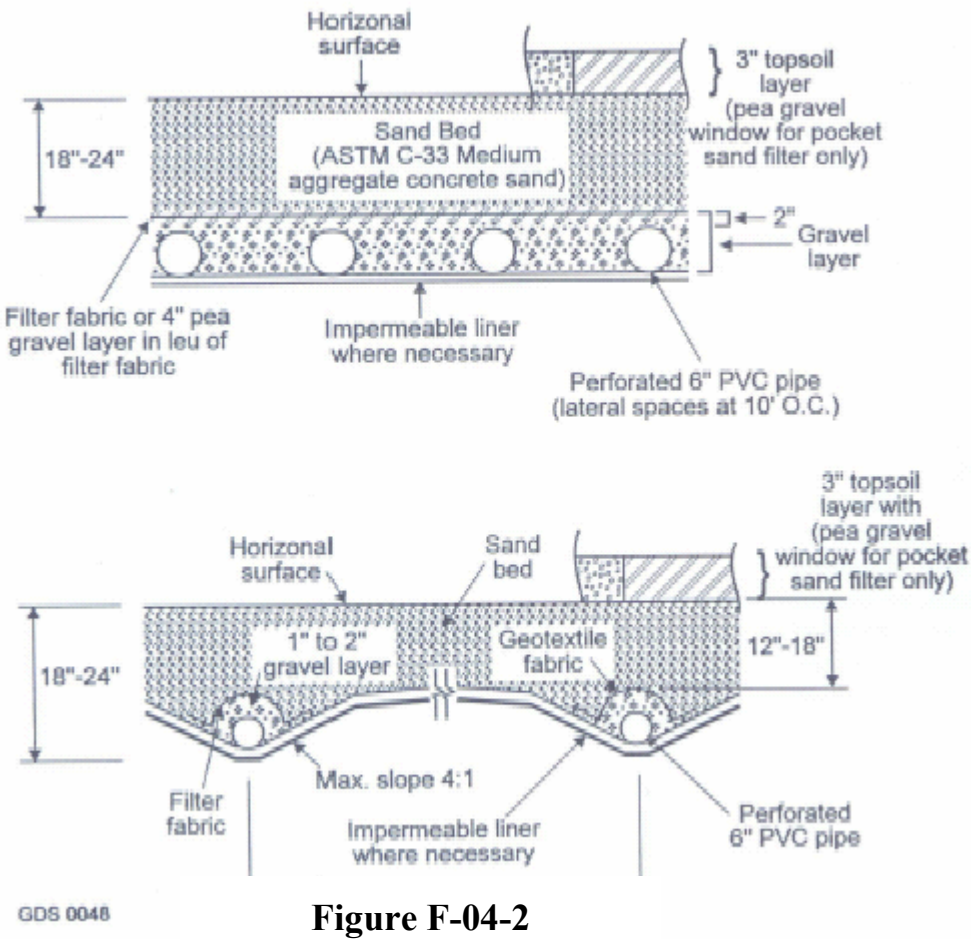


Figure F-04-2
Typical Sand Filter Media
Cross Sections

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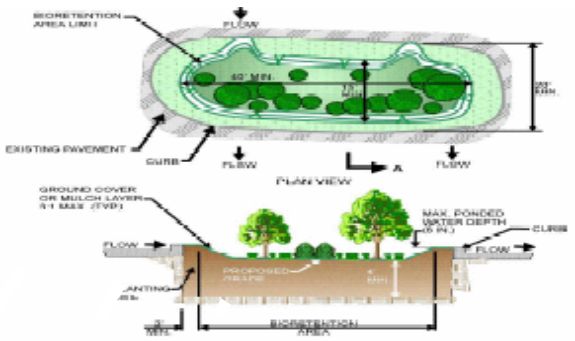
ACTIVITY: Bioretention Basins (Rain Gardens)

F – 05



Targeted Constituents				
● Significant Benefit	◗ Partial Benefit	○ Low or Unknown Benefit		
◗ Sediment	◗ Heavy Metals	○ Floatable Materials	◗ Oxygen Demanding Substances	
◗ Nutrients	◗ Toxic Materials	◗ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes
Implementation Requirements				
● High	◗ Medium	○ Low		
◗ Capital Costs	◗ O & M Costs	◗ Maintenance	○ Training	

Description

The bioretention basin, or "rain garden", was developed by the Prince George's County, Maryland Department of Environmental Protection. It consists of seven components: The grass buffer strip; the ponding area; the surface mulch and planting soil; the sand bed; the organic layer; the plant material; and the infiltration chambers. Bioretention basins are planting areas installed in shallow basins, where stormwater runoff is filtered through the various layers mentioned above. Biological and chemical reactions occur around the roots of the plants, and water infiltrates into the soil below. Bioretention basins enhance stormwater quality through adsorption, filtration, volitization, ion exchange, microbial soil processes, evapotranspiration, nutrient uptake in plants, and decomposition prior to exfiltration into the surrounding soil mass. Such basins also enhance infiltration and groundwater recharge, thus reducing the volume of stormwater runoff.

Selection Criteria

The primary use of this BMP is for water quality control, although they provide some protection against flooding and streambank erosion, depending on the size of the basin. Bioretention basins are suitable for use at any site where the subsoil provides reasonable infiltration, and the water table is sufficiently lower than the design depth of the basin. These basins are usually designed for drainage areas of less than one acre.

Areas that have mature trees that would need to be removed, have slopes greater than 20%, and are above or close to an unstable soil strata are not appropriate areas for rain gardens. In addition, this BMP will not function properly in sites subjected to continuous or frequent flows, as the sand filter will not have time to dry and aerate.

Design and Sizing Considerations

Rain gardens are often located in the following areas:

- Landscaping islands
- Small drainage areas
- Highly impervious areas, such as parking lots

Properly designed rain gardens replicate a dense forest floor, through the use of certain plants, mulches, and nutrient-rich soils. Since rain gardens often have aesthetic value, it is recommended that the designer has working knowledge and design skills of

indigenous horticultural practices, such as a landscape architect.

The size of the facility is based on the amount of impervious surface in the drainage area. For example, for facilities treating the first 0.5 inches of runoff from the impervious areas in the catchment, the surface area of the rain garden is typically small, but should be a minimum of 2.5% of the impervious area. For facilities treating the first 1 inch, the surface area should be a minimum of 5% of the impervious area.

Bioretention areas will typically need to be used in conjunction with another structural control to provide channel protection as well as overbank flood protection. It is important to ensure that a bioretention area safely bypasses higher flows.

Other design elements are as follows:

- The minimum width and length of the rain garden is 10 feet by 15 feet.
- Maximum contributing drainage area is 5 acres. 0.5 to 2 acres are preferred. Multiple rain gardens can be used for larger drainage areas.
- The site slope should be no more than 6%.
- 2 feet distance is recommended between the bioretention facility and the seasonally high water table.
- Rain gardens typically require 5 feet of head.
- The rain garden should be designed to completely drain within 48 hours. They should not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.
- Bioretention area locations should be integrated into the site planning process, and aesthetic considerations should be taken into account in their siting and design. Elevations must be carefully worked out to ensure that the desired runoff flow enters the facility with no more than the maximum design depth.
- The maximum recommended ponding depth of the bioretention areas is 6 inches.

Grass Buffer Strip

The grass buffer strip pretreats the runoff. It filters particles from the stormwater runoff by reducing the velocity. Often, the buffer strip is enhanced with a pea gravel ribbon, to spread the runoff and increase infiltration through the strip. The minimum filter strip length should be 10 feet.

Sand Bed

The sand bed further slows the runoff, and spreads the runoff over the entire basin. As the water infiltrates into the sand, the water is filtered. Drainage must be designed to flow away from the sand bed, in order to guard against anaerobic conditions in the planting area, and provide exfiltration from the basin. The sand bed should be 12 to 18 inches thick. Sand should be clean and have less than 15% silt or clay content.

Ponding Area

The ponding area detains runoff waiting to be treated. It also allows for pre-settling of particulates in the stormwater runoff. The ponding area should be constructed in accordance with Section P-01, Detention Basin. The pond should be equipped with an overflow structure, with its invert elevation 0.5 feet above the organic layer.

Organic Layer

The organic, or mulch, layer filters the pollutants in the runoff, protects the soil from eroding, and provides an environment for microbes to degrade pollutants, such as petroleum-based solvents. The mulch layer may consist of either fine shredded hardwood mulch or shredded hardwood chips, and should be applied uniformly at a depth of 2-3 inches. Grass clippings are not suitable, since they contain excessive quantities of nitrogen that would limit the capability of the rain garden to filter nitrogen in stormwater runoff.

Planting Soil Layer

This layer stores water and nutrients for the plants. Clay particles in the layer adsorb heavy metals, hydrocarbons, and other pollutants. The planting soil bed must be at least 4 feet in depth. Planting soils should be sandy loam, loamy sand, or loam texture.

Plant Material

The plant species should be selected with great care, depending on their ability to treat pollutants through their interaction with other plants, soil, and the organic layer. Other factors to consider when choosing vegetation include climate of the site, shape, growth rates, maintenance requirements, size, hardiness, and type of root system. A variety of plants should be selected, in order to combat insects and disease, and increase envirotranspiration and aesthetic beauty.

Infiltration Chambers

Vented infiltration chambers provide exfiltration through open-bottomed cavities, decrease ponding time above the basin, and aerate the filter media between storms through the cavities and vents to the surface. By providing a valve equipped drawdown drain to daylight, the basin can be converted into a soil media filter should exfiltration surface failures occur.

Underdrain Collection System

The underdrain collection system is equipped with a 6-inch perforated PVC pipe (AASHTO M 252) in an 8-inch gravel layer. The pipe should have 3/8-inch perforations, spaced at 6-inch centers, with a minimum of 4 holes per row. The pipe is spaced at a maximum of 10 feet on center and a minimum grade of 0.5% must be maintained. A permeable filter fabric is placed between the gravel layer and the planting soil bed.

Construction/ Inspection Considerations

Sediment must be controlled during and after construction of the rain garden. Since infiltration is a key component of the rain garden, rain gardens are not recommended as the site of sediment detention basins during construction, as sediments tend to clog underlying soil strata. The bioretention basin will function more efficiently if the entire system is fully stabilized with vegetative and structural practices.

Use relatively light, tracked equipment during construction, to avoid compaction of the basin floor.

Maintenance

The structure and vegetation of the rain garden should be inspected and maintained frequently to assure proper function.

- Pests and weeds should be extracted from the facility.
- The facility should be frequently removed of debris and sediment.
- This BMP requires extensive landscaping.
- Rain gardens are not recommended for areas with steep slopes.

Cost Considerations

This BMP costs more than other filtering systems.

Limitations

A great deal of knowledge of engineering and horticultural knowledge is required for the successful implementation of this BMP. Maintenance and frequent inspections are also necessary.

Additional Information

Examples and applications of several different types of bioretention basins are illustrated on the following pages. The reader is referred to the Tennessee Erosion & Sediment Control Handbook for further discussion on vegetative practices (TDEC, 2002).

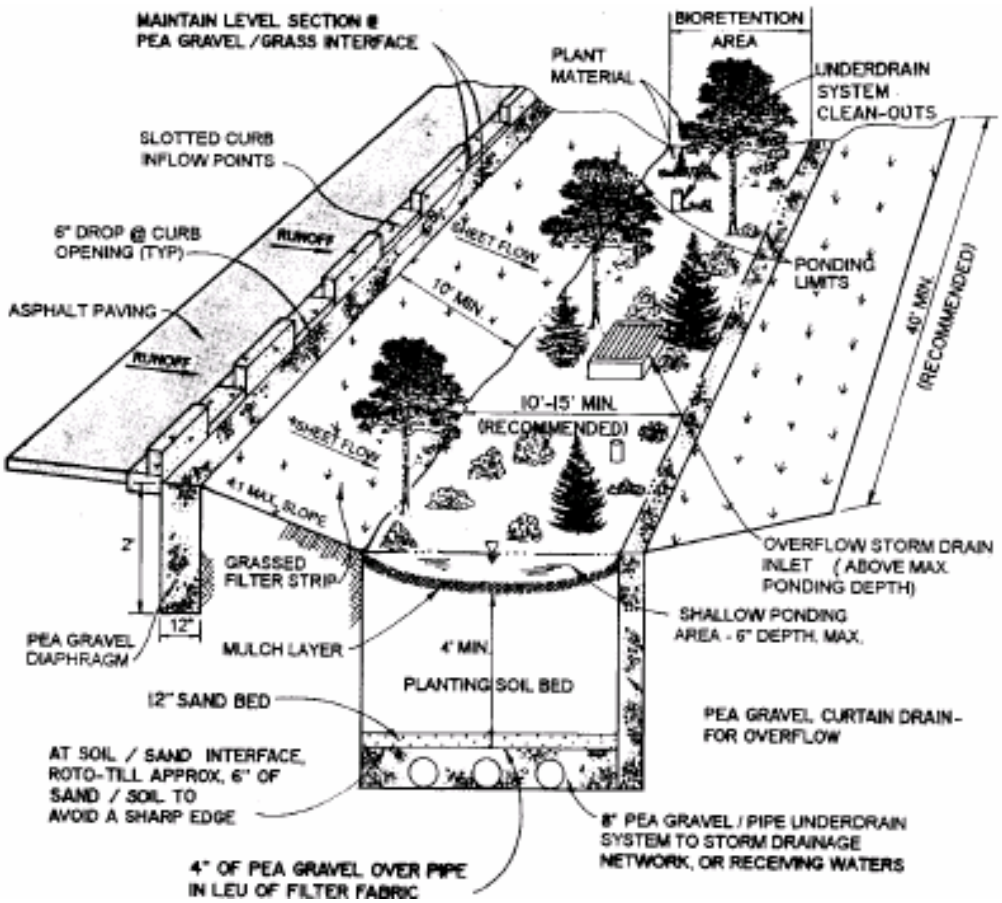


Figure F-05-1 – Bioretention Basin
(Prince George's County, MD, 1993)

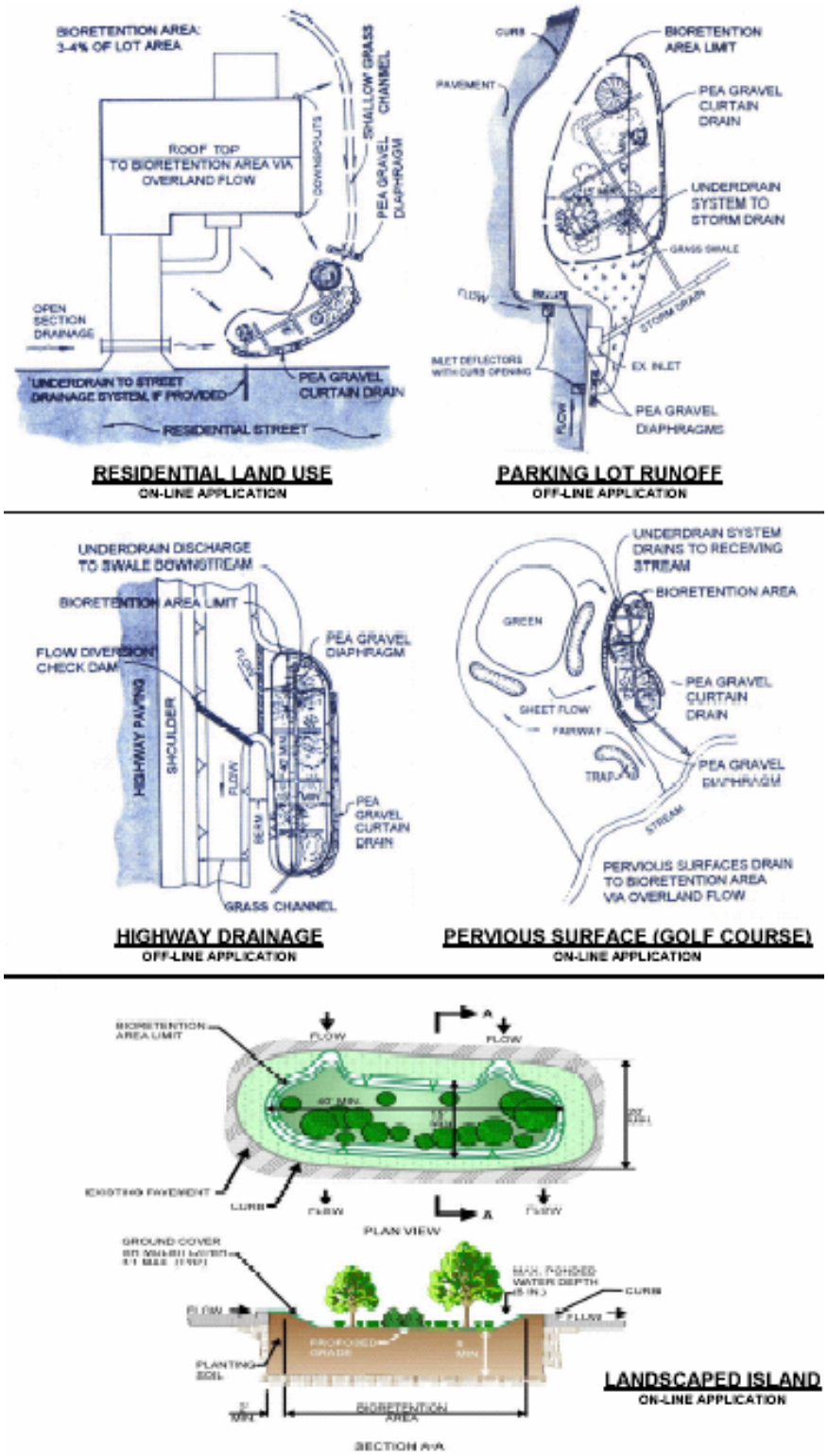


Figure F-05-2 – Bioretention Area Applications (ARC, 2001)

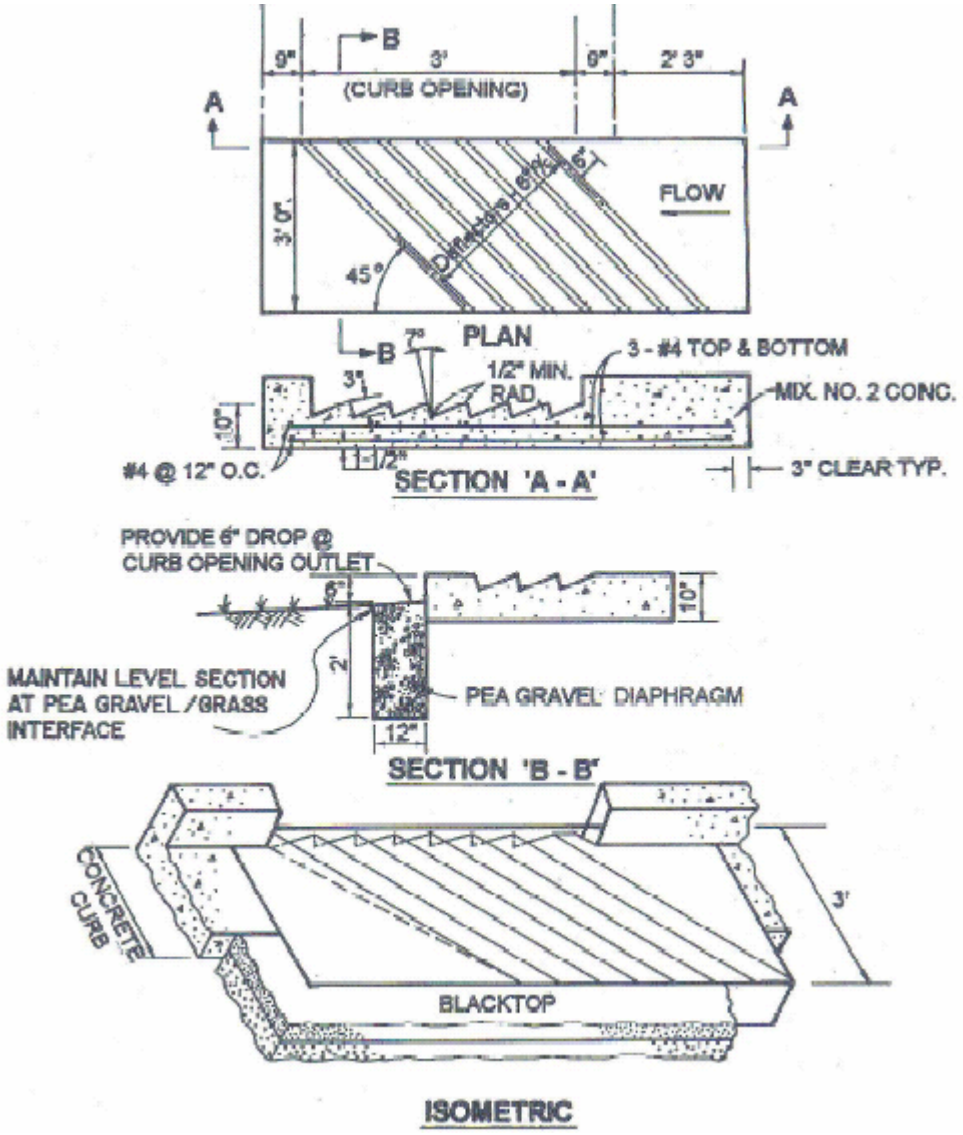


Figure F-05-3 – Typical Inlet Deflector
(Prince George's County, MD, 1993)

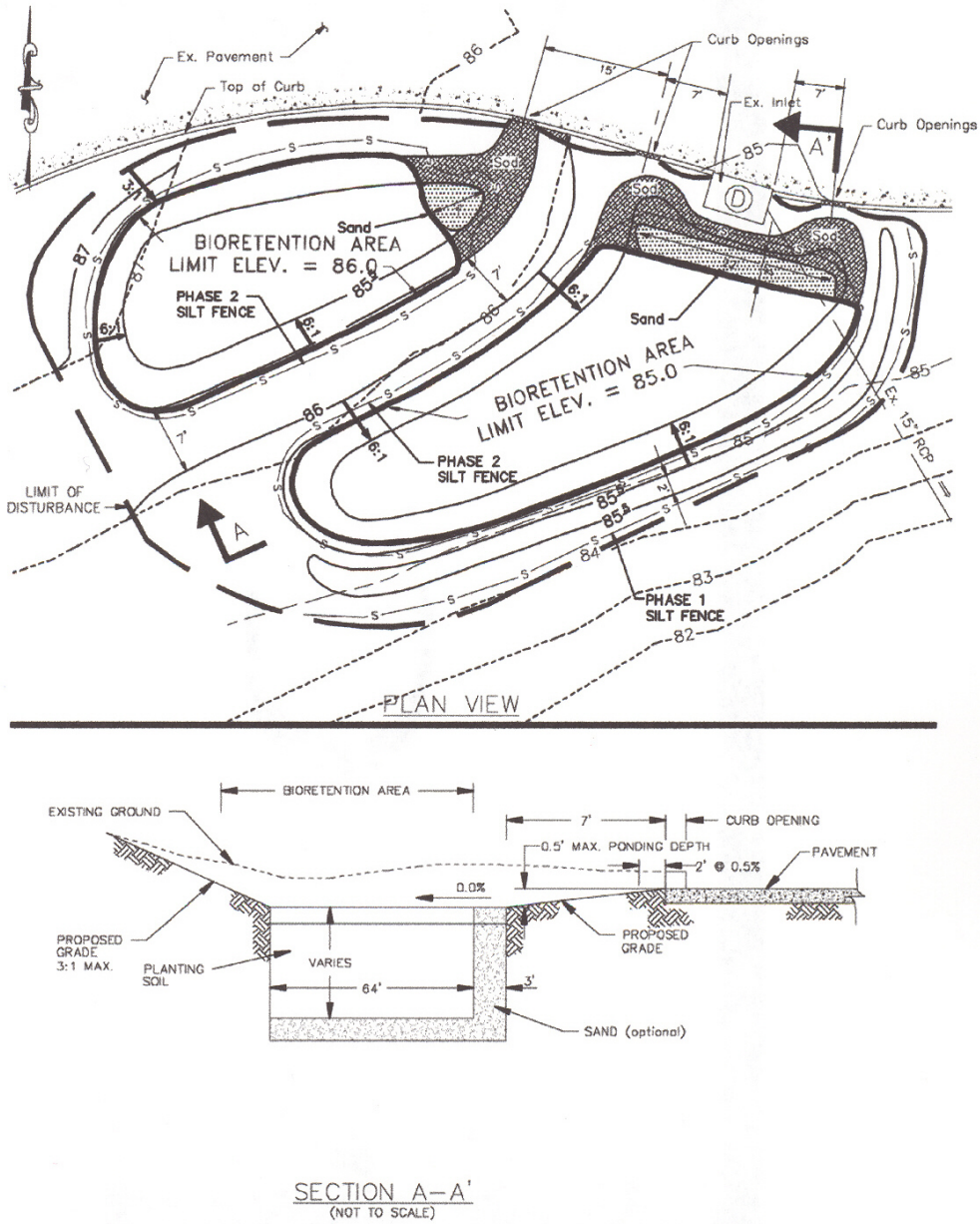


Figure F-05-4 – Grading Plan for Bioretention Basin (Virginia, 1999)

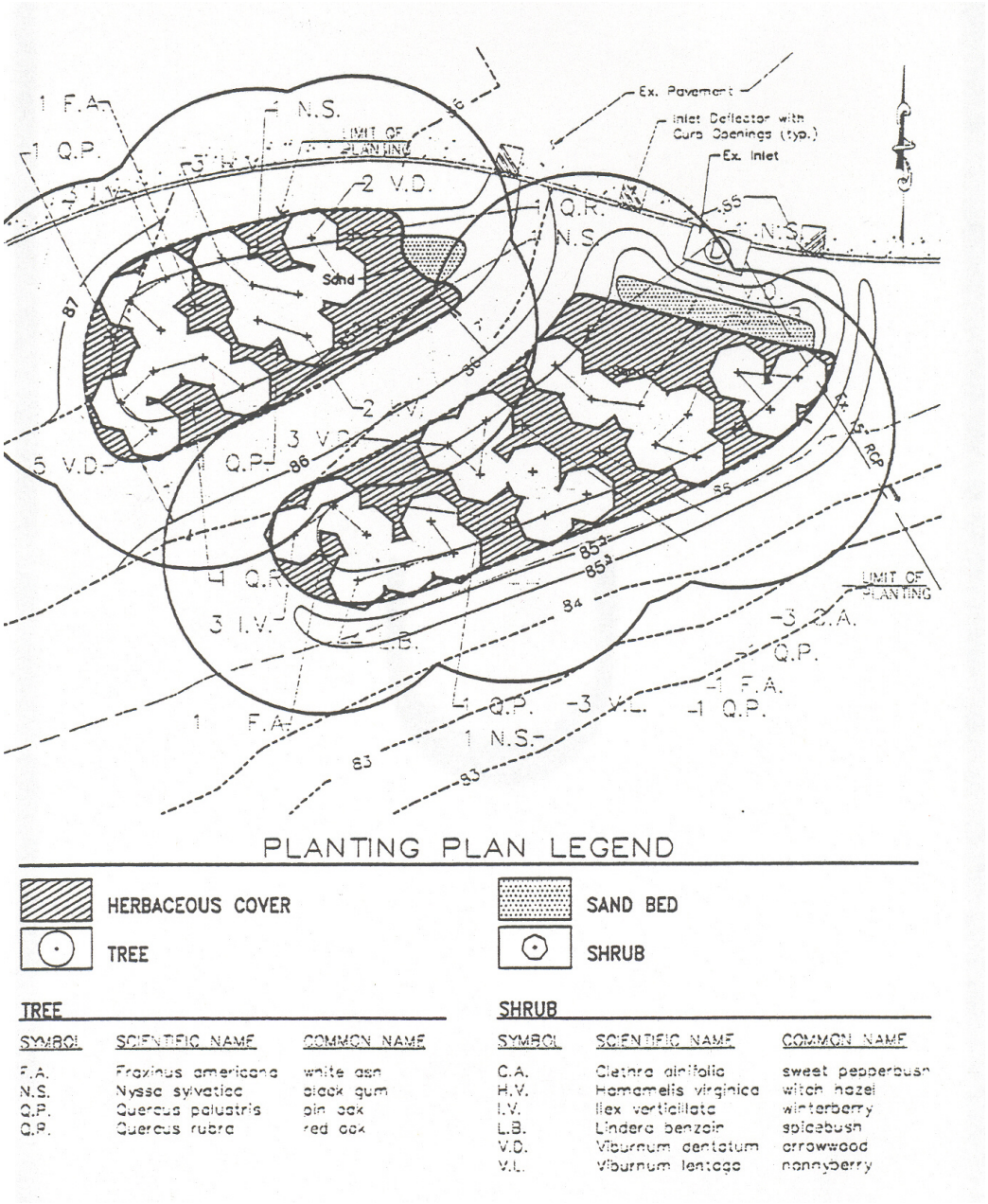


Figure F-05-5 – Sample Planting Plan for Bioretention Basin (Virginia, 1999)

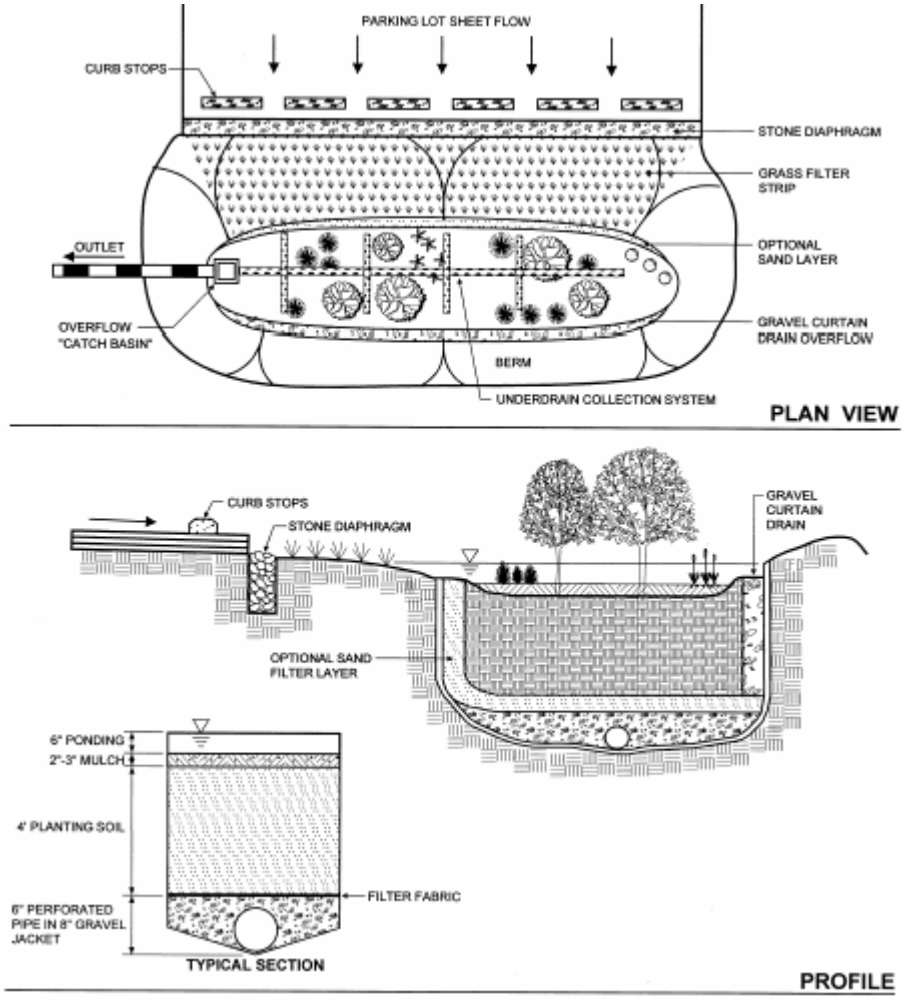


Figure F-05-6 – Typical On-line Bioretention Area (ARC, 2001)

References

Atlanta Regional Commission. *Georgia Stormwater Management Manual.* First edition, 2001.

Prince Georges County, Maryland. *Design Manual of Use of Bioretention in Stormwater Management*, Prince Georges County, 1993.

Tennessee Department of Environment and Conservation (TDEC), *Tennessee Erosion & Sediment Control Handbook – A Guide for Protection of State Waters through the use of Best Management Practices during Land Disturbing Activities*, March 2002.

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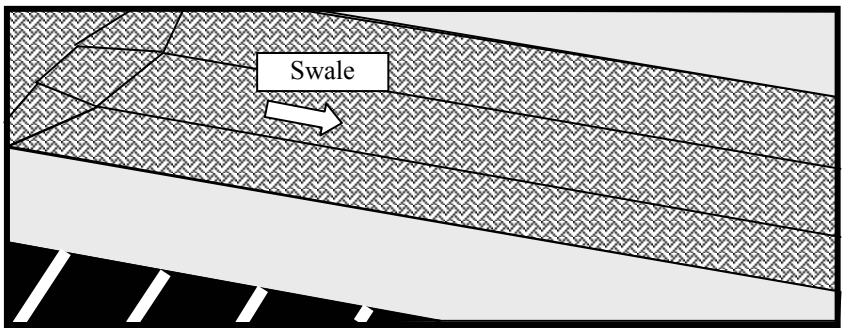
Open Channel - Related BMP Systems

ACTIVITY: Swales

O – 01



Targeted Constituents				
● Significant Benefit		◗ Partial Benefit		○ Low or Unknown Benefit
◗ Sediment	◗ Heavy Metals	○ Floatable Materials	◗ Oxygen Demanding Substances	
◗ Nutrients	◗ Toxic Materials	◗ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes
Implementation Requirements				
● High		◗ Medium		○ Low
◗ Capital Costs	◗ O & M Costs	◗ Maintenance	○ Training	

Description

Swales, one type of open channel, are able to remove some sediments and pollutants from stormwater runoff if correctly designed and constructed. They are capable of controlling peak runoff for small design storms and can enhance the water quality of stormwater runoff by infiltration through the subsoil and filtration through the grass. Low velocities, combined with healthy stands of grass vegetation, allow particles to settle and filter out from stormwater runoff. Generally, a maintained grass filter strip is used to treat sheet flow, and a maintained grass filter swale is used to treat channel flow. This practice will provide a partial reduction in most types of pollutants.

Selection Criteria

- Swales are often used in conjunction with other stormwater management practices to treat runoff from paved streets and parking lots.
- Grass swales are generally used in low-density residential, commercial, or industrial areas and along roadways to replace curb and gutter installation. Because grass swales are not capable of handling large amounts of runoff, they are not useful in highly urbanized areas.
- Swales can also be used to reduce the amount of directly connected impervious area (DCIA) that drains into the storm drainage system, thus reducing peak flows. In addition to pavement applications, swales can be used to drain stormwater from rooftops. Swales reduce runoff volume through increased infiltration potential.

Design and Sizing Considerations

A filter swale is a vegetated open channel which is relatively wide and situated on a mild slope. They are used to slow runoff velocities originating from impervious surfaces that may contain pollutants. A filter swale is designed to have much lower velocities than a normal channel or ditch but still drain adequately. The reader is referred to the theory and practice of design of grass- and vegetation-lined channels by n-VR “retardance method” discussed in Chow (Chow, 1959).

Swales perform well for small light-intensity rainfalls, but typically have little effect on the large design rainfalls used for stormwater detention. Swales help to decrease the velocity of stormwater runoff, which increases its travel time, and thus, its peak flow

rate for short, intense storms. Swales can also be used as a component for enhancing stormwater quality, through filtration and directing runoff flows to detention basins and constructed wetlands, which provide water quality treatment both during and between storms for the large design rainfalls. Swales should generally be used in combination with other stormwater treatment BMPs whenever possible.

Figures O-01-2 illustrates examples of how filter strips and swales can be used in parking lots and residential properties. Since thick and healthy grass vegetation is a part of most landscaped properties, swales are easy to incorporate into most BMP strategies. Swales have removed as much as 80% of total suspended sediments and 50% of soluble zinc in the metropolitan Washington D.C. area if properly constructed, but have not shown any removal for dissolved phosphorous or copper (Metropolitan Washington Council of Governments, 1992). Other studies have also shown little or no removal for heavy metals, and also generally poor performance due to incorrect construction.

The upper layout (Figure O-01-2A - parking lot) shows sheet flow entering a wide swale rather than a gutter or curb inlet. Design considerations include width of swale, the anticipated overhang of vehicles, whether to use wheel stops, and spacing of grate inlets. In general, the grate inlets should flow to a detention basin or other stormwater treatment BMP prior to being discharged to a storm drainage system or natural stream.

The lower layout (Figure O-01-2B – residential property) shows impervious area from rooftops and driveways. Rooftop drainage typically reaches ground level via gutters and downspouts, and it is understood that this stormwater should be conveyed at least 5 to 10 feet from the building to avoid wet basements or saturated foundations. However, downspouts should be turned into sheet flow through filter strips whenever possible.

Swales may be used as a temporary erosion control strategy, in conjunction with other erosion control measures. Swales are used downstream from erosion control measures that remove most coarse sediment and silts from the stormwater. Also, sod (if properly pegged and stabilized) may be used as part of temporary inlet protection in conjunction with silt fence or straw bale barriers.

Filter swales are generally grass-lined channels wider than that which is necessary for conveyance. Other materials may be incorporated into grass-lined channels, such as a gabion wall along one side of the channel or a concrete swale crossing, provided that overall flow velocities are below 1 foot per second.

Filter swales are often constructed around parking lots and commercial centers as recessed planters for landscaping. Filter swales in these areas may also incorporate inlets raised 4 to 6 inches above the swale, which may function as first-flush retention volume for pretreatment if infiltration rates are sufficient (typically 0.2 inches per hour observed field rate). Raised inlets should be constructed in a way that appears different and purposeful, so that the flooded median will not appear to be a case of bad drainage design. For instance, the inlets in Figure O-01-2 may be raised if there is sufficient storage in the median areas to prevent flooding the parking lot. A raised inlet may also be indicated by wetland-type vegetation such as bulrushes, cattails, or sedges.

Filter swales may have level spreaders at the beginning of the swale or landscape timbers spaced at regular intervals throughout the swale. Landscape timbers can be used to reduce the channel slope and increase residence time within the filter swale.

Landscape timbers can also be used as bookends to enclose a "gravel filter", typically 5 to 10 feet long, in the end reach of a swale to trap sediment and pollutants.
The typical channel shape for a filter swale is trapezoidal or parabolic, with side slopes as flat as possible. Typically the eroding velocity is checked for the mowed condition, while the flow depth and capacity are checked for the unmowed, higher retardance condition (i.e., SCS n-VR "retardance method"). Channel roughness characteristics depend heavily on the height of grass, so that the mowed and unmowed conditions will yield significantly different velocities and flow depths.

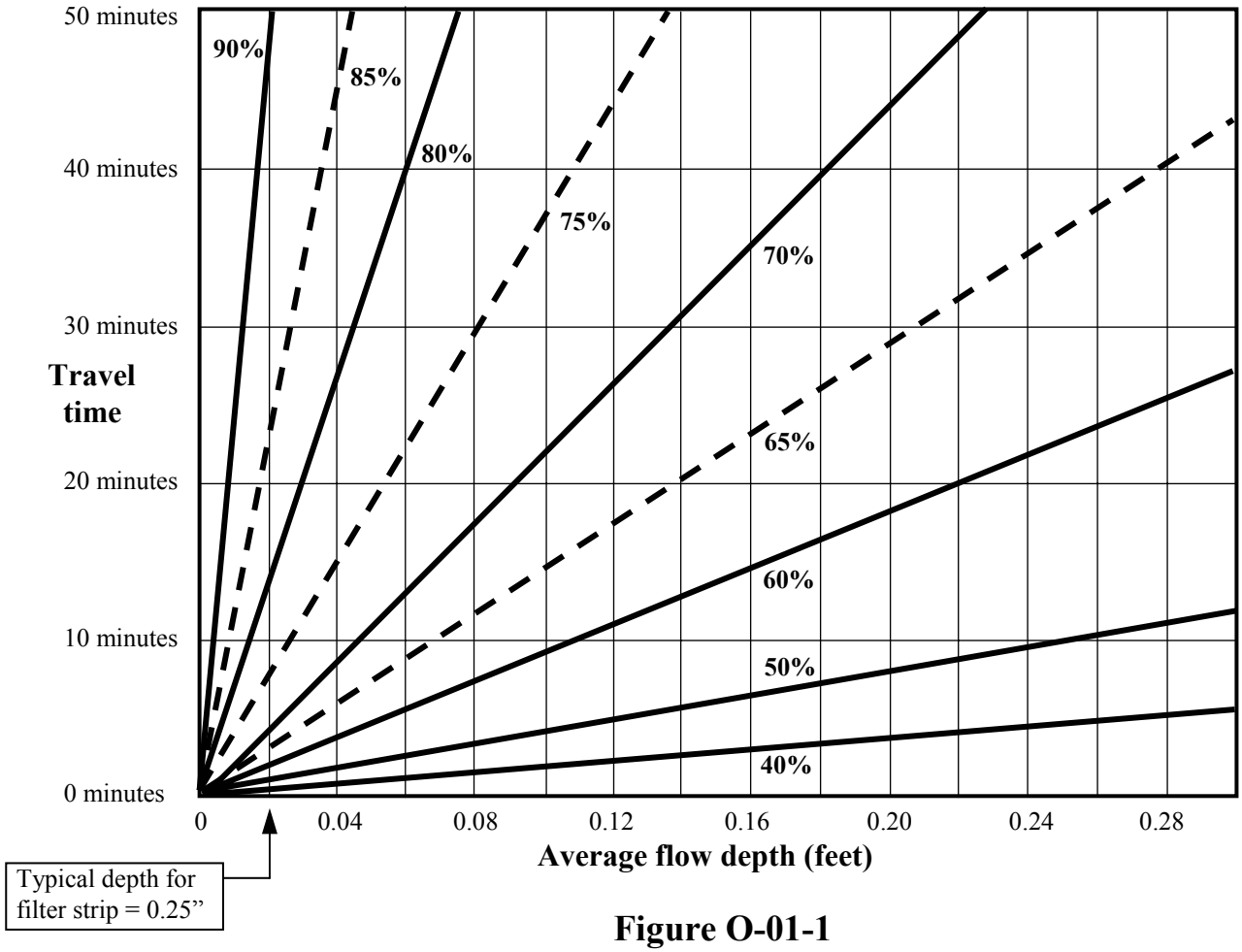


Figure O-01-1
TSS Removal Efficiency for Grass Swales and Filters

Pollutant Removal Efficiency

Grass swales and ditches should generally be designed for a minimum 10-year storm in order to verify adequate capacity. However, the average mean rainfall is generally used to analyze the total suspended sediment (TSS) removal efficiency, which is shown above in Figure O-01-1 and comes from the Federal Highway Administration.

Other design factors are as follows:

- Check dams can be installed to slow down the flow of runoff, to increase the time

for infiltration, and to allow for slightly steeper slopes.

- Long channels (> 200 feet) maximize pollutant removal and increase runoff contact time. The minimum swale length should be 100 feet.
- Channel slopes greater then two percent prevent ponding, and slopes less then five percent help maintain slow velocities within the swale and increase pollution settlement.
- Highly permeable subsoils are beneficial for maximizing infiltration.
- Dense grass in the swale promotes filtration of runoff and pollutant removal.
- Designing for small storms with a peak discharge less than 5 cubic feet per second maximizes performance of the swale and allows for drying between storms.
- Whenever possible, it is good practice to remove high concentrations of oil and grease before entrance into the swale.
- Grass swales function best on highly permeable soils. Infiltration rates of 0.5 inches per hour or more are recommended.
- The bottom width should be between two and ten feet.
- The depth of flow within a grass swale should not exceed the height of the grass, which averages around four inches.
- The bottom of a grass swale should be at least two feet above the water table.
- The longer stormwater runoff is in contact with the grass swale, the greater its pollutant removal capability. Using the appropriate grass cover along with the proper slope, width, and length of swale can greatly increase contact time and pollutant removal. Installing check dams within the grass swale can increase contact time by allowing runoff to pond behind them.
- Grass swales are very susceptible to erosion in highly urbanized areas because of the amount of impervious surfaces.
- Many existing low-density residential, industrial, and commercial areas already have existing grass channels. Retrofitting is possible; however, if the appropriate land area is available. Adding check dams is a good way of improving upon existing grass swales.

Construction/ Inspection Considerations

Swales should not normally be used to carry runoff during construction, since grass swales do not function properly when clogged with sediment.

Sod Placement

Sodded grass is preferable to seeded grass vegetation, but either method may be used to establish grass swales. Sod has the advantages of immediate erosion control and stormwater treatment, healthier stands of vegetation, aesthetics, less maintenance and less inspection, and increased property values. Refer to Figure O-01-3 for a relative comparison of various types of turf grass; information is also available from the UT Agricultural Extension website.

Protect sod with tarps or other covers during delivery so that it does not dry out between harvesting and placement. Prepare subgrade by removing all weeds and

debris, and then add fertilizer, lime and water as needed. Place sod in staggered fashion so that there are no long seams. After placing sod, lightly roll to eliminate air pockets and ensure close contact with the soil. After rolling, the sodded areas shall be watered so that the soil is moistened to a minimum depth of 4 inches. Sod should not be planted during very hot or wet weather. Do not place sod on slopes that are greater than 3H:1V if they are to be mowed.

Maintenance

- Swales should be inspected regularly during the establishment of vegetation. Repair or replace any damage to the sod, vegetation, or evenness of grade as needed. Look for signs of erosion, distressed vegetation or channelization of sheet flow.
- In general, grass vegetation should not be mowed shorter than 3 inches. Maximum recommended length of grass is 6 to 8 inches. Allowing the grass to grow taller may cause it to thin and become less effective. The clippings should be bagged and removed. Mowing grass regularly promotes growth and pollutant uptake.
- Keep all level spreaders or check dams even and free of debris. Remove sediment and debris by hand and with a flat-bottomed shovel during dry periods, leaving as much of the vegetation in place as possible. Reseed or plug any damaged turf or vegetation.
- As with most BMPs, the burden of maintenance falls on the homeowner. Thus, a crucial factor in maintenance is educating the owner on the necessary conditions of a functioning grass swale. They require periodic mowing (again, never mowing too close to the ground), occasional reseeding, watering during drought periods, and sediment removal.
- Minimizing pesticide use on adjacent lawns is important in reducing the chemical pollutants to the water.

Sediment Removal

- The sediment accumulation rate is dependent on a number of factors such as land use, watershed size, types of industry, nearby construction, etc. The sediment composition should be identified before being removed and disposed.
- Some sediment may contain contaminants for which the Tennessee Department of Environment and Conservation (TDEC) requires special disposal procedures. Consult TDEC - Division of Water Pollution Control if there is any uncertainty about what the sediment contains or if it is known to contain contaminants. Generally, special attention or sampling should be given to sediments accumulated in facilities serving industrial, manufacturing or heavy commercial sites, fueling centers or automotive maintenance areas, large parking areas, or other areas where pollutants are suspected to accumulate.
- Clean sediment can be used as fill material, hole filling, or land spreading. It is important that this material not be placed in a way that will promote or allow resuspension in storm runoff.

Cost Considerations

Although grass swales may require more land then curb and gutter installations, they are cheaper to construct. Estimates for cost range between $5 and $15 per linear foot, depending on dimensions, and labor and materials costs.

Limitations

- Swales are effective only on gentle slopes, typically less than 1 or 2 percent. Swales located on steeper slopes generally will not receive credit as being a stormwater treatment BMP. Site topography may not allow the use of swales. Grass swales typically must be very long to accomplish stormwater flow reduction and stormwater quality equal to a detention basin.
- Swales are useful primarily for small areas only, typically 1 acre or less. Larger project sites or properties can also make effective use of swales for smaller subbasins.
- Grass swales are often ineffective in areas with a peak discharge greater than 5 cubic feet per second because water quantity and quality benefits are drastically reduced.
- The groundwater quality could be affected by infiltration through the grass swale. Trace metals and nutrients in the runoff could be increased if leaching from culverts and fertilized lawns occurred.
- Standing water in a grass swale could pose neighborhood safety concerns as well as potential odors and mosquito problems.
- Proper maintenance is required to maintain the health and density of grass vegetation, such as irrigation during summer droughts and adding small amounts of fertilizer or lime as needed.
- If the side slopes of a grass swale are too steep and the flow velocity becomes too great, erosion of the swale can become a problem by adding sediment to the runoff water, reducing infiltration rate, and not providing intended filtration.

  Likewise, if substantial runoff enters a swale during the dry season, inappropriate grass cover could hinder infiltration rates and reduce the effectiveness of the swale.
- Runoff from fertilized lawns into the swale system could increase the pollutant load.

Additional Information

Examples illustrating swale applications are shown in the following figures.

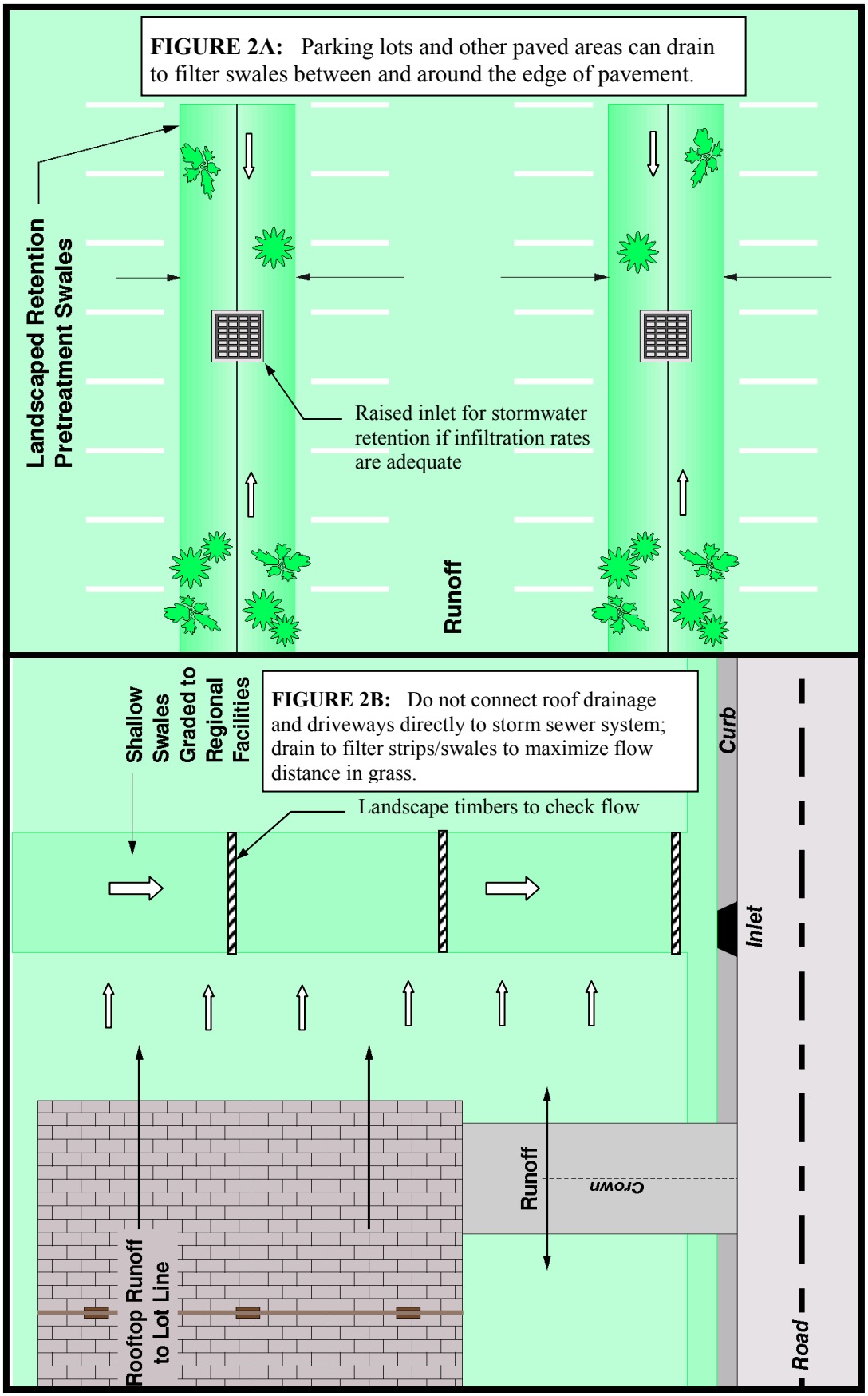


FIGURE 2A: Parking lots and other paved areas can drain to filter swales between and around the edge of pavement.

FIGURE 2B: Do not connect roof drainage and driveways directly to storm sewer system; drain to filter strips/swales to maximize flow distance in grass.

Figure O-01-2
Examples of Filter Strips and Swales

COLD TOLERANCE (winter color persistance)

High
- Creeping bentgrass
- Kentucky bluegrass
- Red fescue
- Colonial bentgrass
- Highland bentgrass
- Perennial ryegrass
- Tall fescue
- Weeping alkaligrass
- Dichondra
- Zoysiagrass
- Common bermudagrass
- Hybrid bermudagrass
- Kikuyugrass
- Seashore paspalum
- St. Augustinegrass

Low

HEAT TOLERANCE

High
- Zoysiagrass
- Hybrid bermudagrass
- Common bermudagrass
- Seashore paspalum
- St. Augustinegrass
- Kikuyugrass
- Tall fescue
- Dichondra
- Creeping bentgrass
- Kentucky bluegrass
- Highland bentgrass
- Perennial ryegrass
- Colonial bentgrass
- Weeping alkaligrass
- Red fescue

Low

MOWING HEIGHT ADAPTATION

High cut
- Tall fescue
- Red fescue
- Kentucky bluegrass
- Perennial ryegrass
- Weeping alkaligrass
- St. Augustinegrass
- Common bermudagrass
- Dichondra
- Kikuyugrass
- Colonial bentgrass
- Highland bentgrass
- Zoysiagrass
- Seashore paspalum
- Hybrid bermudagrass
- Creeping bentgrass

Low Cut

DROUGHT TOLERANCE

High
- Hybrid bermudagrass
- Zoysiagrass
- Common bermudagrass
- Seashore paspalum
- St. Augustinegrass
- Kikuyugrass
- Tall fescue
- Red fescue
- Kentucky bluegrass
- Perennial ryegrass
- Highland bentgrass
- Creeping bentgrass
- Colonial bentgrass
- Weeping alkaligrass
- Dichondra

Low

MAINTENANCE COST AND EFFORT

High
- Creeping bentgrass
- Dichondra
- Hybrid bermudagrass
- Kentucky bluegrass
- Colonial bentgrass
- Seashore paspalum
- Perennial ryegrass
- St. Augustinegrass
- Highland bentgrass
- Zoysiagrass
- Tall fescue
- Common bermudagrass
- Kikuyugrass

Low

Taken from California Cooperative Agricultural Extension (1984)

Figure O-01-3
Characteristics of Various Types of Grass

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Appendix A

Case References

Appendix A – Case References

Example Judicial Decisions Arising From Natural Water and Water Course Drainage Cases in Tennessee

Natural Water Courses

Obstruction and detention:

Cox v. Howell, 65 S.W. 868, 108 Tenn. 130, 58 L.R.A. 487 (Tenn.1901)

The owner of land, across or over which a stream of water flows, has a right to have it flow over his land in its natural channel, without unreasonable detention, undiminished in quantity, and unimpaired in quality, except so far as it inseparable from a reasonable use of the water of the stream for the ordinary and useful purposes of life by those above him on the stream.

Pollution:

Sumner v. O'Dell, 12 Tenn. App. 496 (Tenn.App. 1930)

Whether or not the pollution of the waters of a stream is an actual injury to a lower riparian proprietor depends upon whether it is the result of such reasonable use of the stream as the upper owner is entitled to make, or an unreasonable use in excess of his rights.

Surface Waters

Obstruction or repulsion of flow:

Zollinger v. Carter, 837 S.W. 2d 613, appeal denied (Tenn. App. 1992)

Wrongful interference with natural drainage of surface water which causes injury to adjoining landowner constitutes actionable nuisance.

Blackwell v. Butler, 582 S.W.2d 760 (Tenn. App. 1978)

Common enemy rule in regard to natural flow of drainage and obstruction of surface waters does not apply in Tennessee.

Woodlawn Memorial Park of Nashville, Inc. v. L & N Railroad Co., Inc., 377 F. Supp. 932 (D.C.Tenn. 1972)

Under law of Tennessee, all lands are of necessity burdened with servitude of receiving and discharging all waters which flow down to them from higher lands.

Rule that lands lying at a lower level are burdened with servitude of receiving all waters which naturally flow down to them from lands adjoining, and upon a higher level, has been adopted and applied in Tennessee, not only to living streams, springs, etc., but also to surface water, and waters falling as rain or snow upon such higher lands.

Under law of Tennessee, proprietor may protect his lands from injurious effects of surface water if, in thus relieving himself, he respects the rights of others.

Carland v. Aurin, 53 S.W. 940, 103 Tenn. 555, 48 L.R.A. 862, 76 Am.St.Rep. 699 (Tenn. 1899)

A landowner, whether in country or city, has an easement for drainage of surface water in its natural flow over the lower lands of a neighboring owner, and if the latter places an obstruction of any character upon his land that arrests this drainage, and thereby causes injury to the former, an action lies for the damages.

Drainage or discharge:

William B. Shearron, et al, v. The Tucker Corporation, et al., appeal upheld (Tenn. App. 2000)

The plaintiff sued the developer of a subdivision adjacent to their property for digging a drainage ditch that caused frequent flooding. The defendant filed counter-claims, including an allegation that the plaintiffs and the previous owners of his property had conspired to breach the agreement to sell the property to the developer. The developer also argued that the city had taken steps to alleviate the flooding. The trial court found that the developer had created a permanent nuisance by changing the natural flow of water across his property, and dismissed the developer's counter claims. On appeal, the appellate court affirmed the trial court's finding of a nuisance, but concluded that the circumstances created both a temporary and a permanent nuisance, and remanded for recalculation of damages based on this holding. The Appellate Court noted in its opinion that, "it is well-settled that if a property owner changes the natural flow of water across his land in a manner that causes flooding on adjacent property, he is liable for creating a nuisance" (see. Zollinger v. Carter (Tenn. App. 1992). The Appellate Court cited Bennett v. Cumberland Hardwoods, Inc., (Tenn. App. 1992), in upholding that both a temporary nuisance and a permanent nuisance were created by interference with the natural flow of water, resulting in flooding on the plaintiff's property. The trial court's dismissal of Defendant's breach of contract claims was upheld.

Miller v. City of Brentwood, 548 S. W.2d 878 (1976, abridged opinion, April 1, 1977).

Plaintiffs, property owners in a subdivision, sued the City of Brentwood, Tennessee, alleging that the city, by granting building permits for construction which reduced the absorption of rainfall into the earth, authorized and permitted an increase in the "runoff" of water. They alleged this overtaxed a drainage ditch passing by and/or through their properties, located in the lower portion of the subdivision, thereby causing flooding and damage to their property. The lower court held that the city had caused the increased flooding of plaintiffs' properties and thereby created an actionable nuisance, entitling plaintiffs to appropriate injunctive relief. On appeal the Court of Appeals of Tennessee, Middle Section, reversed the lower court's decree, vacated all relief granted, and dismissed the plaintiffs' suit. Excerpts from the opinion given by the Court of Appeals include:

Even if it be accepted that part of plaintiffs' troubles arise from construction authorized by the city, this does not establish plaintiffs' rights against the city.

The right of action, if any, for plaintiffs' injuries is directly against those who caused the problem, i.e., the owners of property which is producing the unnatural amount of surface water.

No right of action is recognized against a municipality for issuing a permit for construction in accordance with exiting laws and regulations. Correspondingly, there is no authority for the Courts to enjoin the issuance of a permit, otherwise lawful, for the reason that its use might result in a private injury.

It is the conclusion of this Court that no right of action whatever exists against the city in the present circumstances.

Chrisman v. Hill Home Development, Inc., et al, appeal denied (Tenn. App. 1997)

While the respective role of each defendant was essentially admitted on drainage nuisance liability and design negligence, the appellate court held the statutes of repose and limitations applicable: [T]he statute of limitations for damages to real property is three (3) years from the accrual of the cause of action (T.C.A. ' 28-3-105. Allied with the delimiting period is one of repose, T.C.A. ' 28-3-202, which provides that all actions to

recover damages for engineering negligence must be brought within four years after the substantial completion of the project. Summary judgment was granted to plaintiffs.

Britton v. Claiborne County, 898 S.W.2d 220, rehearing denied, and appeal denied (Tenn. App. 1994)

Where property owners are damaged by runoff from drainage ditch as result of a private individual construction of property improvement, right of action for damaged property owners, if any, was directly against those who caused problem.

Winn v. Tucker Corp., 848 S.W.2d 64 (Tenn.App. 1992)

Contractors who built drainage ditch that diverted natural flow of water onto landowners' land could not escape liability for damage to land by alleging that city had approved plan for ditch and had later participated in remedial measures to correct problems.

Zollinger v. Carter, 837 S.W. 2d 613, appeal denied (Tenn.App. 1992)

If owner of higher lands alters natural condition of property so that surface waters collect and pour in concentrated form or in unnatural quantities upon lower lands, owner will be responsible for all damages caused thereby to possessor of lower lands.

An Act of God defense did not apply to absolve landowner of liability for flooding of adjacent residences due to change in surface water drainage caused by landowner's development; feature of landowner's construction work was an intervening cause to the heavy and unusual rainfall.

Brown v. City of Kingsport, 711 S.W.2d 607 (Tenn.App. 1986)

Upper riparian owners have a legal duty of care not to interfere with natural surface water runoff which would expose others to an unreasonable risk of harm.

Gregory v. Jenkins, 665 S.W.2d 397 (Tenn.App. 1983)

Dominant tenement may not channelize natural flow of water into small pathway so that it enters upon lands of servient tenement with unnatural destructive force.

Butts v. City of South Fulton, 565 S.W.2d 879 (Tenn.App. 1977)

Wrongful interference with natural drainage of surface water causing injury to adjoining landowner constitutes actionable nuisance.

Woodlawn Memorial Park of Nashville, Inc. v. L & N Railroad Co, Inc., 377 F.Supp. 932 (D.C.Tenn. 1972)

If proprietor of higher lands alters natural condition of his property, and collects surface and rainwater together at bottom of his estate and pours it in a concentrated form and in unnatural quantities upon land below, he will be responsible under law of Tennessee for all damage thereof caused to possessor of lower lands.

Kind v. Johnson City, 478 S.W.2d 63, 63 Tenn.App. 666 (Tenn.App. 1970)

Wrongful interference with natural drainage of surface water causing injury to adjoining landowner constitutes actionable nuisance.

Slatten v. Mitchell, 124 S.W.2d 310, 22 Tenn.App. 547, (Tenn.App. 1939)

The proprietor of higher land may not alter natural condition of his property so as to collect surface water at bottom of his estate and pour it in unnatural quantities on land below, but may protect his lands from injurious effects of surface water if in doing so he respects rights of others.

Louisville & N.R. C. v. Hays, 79 Tenn. 382, 11 Lea 382, 47 Am.Rep. 291 (Tenn. 1883)

All lands are of necessity burdened with the servitude of receiving and discharging all waters which flow down to them from lands on a higher level; the owner of the lower

land is liable when he, without grant or prescription, by artificial means, dams up the water and causes it to overflow the higher lands, and the owner of the higher lands, when he collects the water and pours it in a concentrated form or unnatural quantities upon the lower lands. This rule embraces rain and surface water as well as running streams.

Appendix B

Model Stormwater Ordinance

MODEL STORMWATER ORDINANCE

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July, 2002

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MODEL STORMWATER ORDINANCE

Section 1. General provisions. (1). Purpose. It is the purpose of this ordinance to:

(a) Protect, maintain, and enhance the environment of the City of _____ and the public health, safety and the general welfare of the citizens of the city, by controlling discharges of pollutants to the city's stormwater system and to maintain and improve the quality of the receiving waters into which the stormwater outfalls flow, including, without limitation, lakes, rivers, streams, ponds, wetlands, and groundwater of the city.

(b) Enable the City of _____ to comply with the National Pollution Discharge Elimination System permit (NPDES) and applicable regulations, 40 CFR §122.26 for stormwater discharges.

(c) Allow the City of _____ to exercise the powers granted in Tennessee Code Annotated §68-221-1105, which provides that, among other powers municipalities have with respect to stormwater facilities, is the power by ordinance or resolution to:

(1) Exercise general regulation over the planning, location, construction, and operation and maintenance of stormwater facilities in the municipality, whether or not owned and operated by the municipality;

(2) Adopt any rules and regulations deemed necessary to accomplish the purposes of this statute, including the adoption of a system of fees for services and permits;

(3) Establish standards to regulate the quantity of stormwater discharged and to regulate stormwater contaminants as may be necessary to protect water quality;

(4) Review and approve plans and plats for stormwater management in proposed subdivisions or commercial developments;

(5) Issue permits for stormwater discharges, or for the construction, alteration, extension, or repair of stormwater facilities;

(6) Suspend or revoke permits when it is determined that the permittee has violated any applicable ordinance, resolution, or condition of the permit;

(7) Regulate and prohibit discharges into stormwater facilities of sanitary, industrial, or commercial sewage or waters that have otherwise been contaminated; and

(8) Expend funds to remediate or mitigate the detrimental effects of contaminated land or other sources of stormwater contamination, whether public or private.

(2). Administering entity. The _____ **(stormwater utility)** shall administer the provisions of this ordinance.

[NOTE: Many municipalities will not establish a stormwater utility to administer this ordinance. The public works or other department of the municipality could be designated by the municipal governing body to perform such functions. In such cases the ordinance will need to be modified accordingly.]

Section 2. Definitions. For the purpose of this chapter, the following definitions shall apply: Words used in the singular shall include the plural, and the plural shall include the singular; words used in the present tense shall include the future tense. The word "shall" is mandatory and not discretionary. The word "may" is permissive. Words not defined in this section shall be construed to have the meaning given by common and ordinary use as defined in the latest edition of Webster's Dictionary.

(1) *"As built plans"* means drawings depicting conditions as they were actually constructed.

(2) *"Best management practices"* or *"BMPs"* are physical, structural, and/or managerial practices that, when used singly or in combination, prevent or reduce pollution of water, that have been approved by the City of _____, and that have been incorporated by reference into this ordinance as if fully set out therein.

[NOTE: See § 5(1) for recommended BMP manual.]

(3) *"Channel"* means a natural or artificial watercourse with a definite bed and banks that conducts flowing water continuously or periodically.

(4) *"Community water"* means any and all rivers, streams, creeks, branches, lakes, reservoirs, ponds, drainage systems, springs, wetlands, wells and other bodies of surface or subsurface water, natural or artificial, lying within or forming a part of the boundaries of the City of _____.

(5) *"Contaminant"* means any physical, chemical, biological, or radiological substance or matter in water.

(6) *"Design storm event"* means a hypothetical storm event, of a given frequency interval and duration, used in the analysis and design of a stormwater facility.

(7) *"Discharge"* means dispose, deposit, spill, pour, inject, seep, dump, leak or place by any means, or that which is disposed, deposited, spilled, poured, injected, seeped, dumped, leaked, or placed by any means including any direct or indirect entry of any solid or liquid matter into the municipal separate storm sewer system.

(8) *"Easement"* means an acquired privilege or right of use or enjoyment that a person, party, firm, corporation, municipality or other legal entity has in the land of another.

(9) *"Erosion"* means the removal of soil particles by the action of water, wind, ice or other geological agents, whether naturally occurring or acting in conjunction with or promoted by anthropogenic activities or effects.

(10) *"Erosion and sediment control plan"* means a written plan (including drawings or other graphic representations) that is designed to minimize the accelerated erosion and sediment runoff at a site during construction activities.

(11) *"Hotspot" ("priority area")* means an area where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in stormwater.

(12) *"Illicit connections*" means illegal and/or unauthorized connections to the municipal separate stormwater system whether or not such connections result in discharges into that system.

(13) *"Illicit discharge"* means any discharge to the municipal separate storm sewer system that is not composed entirely of stormwater and not specifically exempted under §3(3).

(14) *"Land disturbing activity"* means any activity on property that results in a change in the existing soil cover (both vegetative and non-vegetative) and/or the existing soil topography. Land-disturbing activities include, but are not limited to, development, re-development, demolition, construction, reconstruction, clearing, grading, filling, and excavation.

(15) *"Maintenance"* means any activity that is necessary to keep a stormwater facility in good working order so as to function as designed. Maintenance shall include complete reconstruction of a stormwater facility if reconstruction is needed in order to restore the facility to its original operational design parameters. Maintenance shall also include the correction of any problem on the site property that may directly impair the functions of the stormwater facility.

(16) *"Maintenance agreement"* means a document recorded in the land records that acts as a property deed restriction, and which provides for long-term maintenance of stormwater management practices.

(17) *"Municipal separate storm sewer system (MS4)" ("Municipal separate stormwater system")* means the conveyances owned or operated by the

municipality for the collection and transportation of stormwater, including the roads and streets and their drainage systems, catch basins, curbs, gutters, ditches, man-made channels, and storm drains.

(18) *"National Pollutant Discharge Elimination System permit"* or *"NPDES permit"* means a permit issued pursuant to 33 U.S.C. 1342.

(19) *"Off-site facility"* means a structural BMP located outside the subject property boundary described in the permit application for land development activity.

(20) *"On-site facility"* means a structural BMP located within the subject property boundary described in the permit application for land development activity.

(21) *"Peak flow"* means the maximum instantaneous rate of flow of water at a particular point resulting from a storm event.

(22) *"Person"* means any and all persons, natural or artificial, including any individual, firm or association and any municipal or private corporation organized or existing under the laws of this or any other state or country.

(23) *"Priority area"* means "hot spot" as defined in § 2(11).

(24) *"Runoff"* means that portion of the precipitation on a drainage area that is discharged from the area into the municipal separate stormwater system.

(25) *"Sediment"* means solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

(26) *"Sedimentation"* means soil particles suspended in stormwater that can settle in stream beds and disrupt the natural flow of the stream.

(27) *"Soils Report"* means a study of soils on a subject property with the primary purpose of characterizing and describing the soils. The soils report shall be prepared by a qualified soils engineer, who shall be directly involved in the soil characterization either by performing the investigation or by directly supervising employees.

(28) *"Stabilization"* means providing adequate measures, vegetative and/or structural, that will prevent erosion from occurring.

(29) *"Stormwater"* means stormwater runoff, snow melt runoff, surface runoff, street wash waters related to street cleaning or maintenance, infiltration and drainage.

(30) *"Stormwater management"* means the programs to maintain quality and quantity of stormwater runoff to pre-development levels.

(31) *"Stormwater management facilities"* means the drainage structures, conduits, ditches, combined sewers, sewers, and all device appurtenances by means of which stormwater is collected, transported, pumped, treated or disposed of.

(32) *"Stormwater management plan"* means the set of drawings and other documents that comprise all the information and specifications for the programs, drainagesystems, structures, BMPs, concepts and techniques intended to maintain or restore quality and quantity of stormwater runoff to pre-development levels.

(33) *"Stormwater runoff"* means flow on the surface of the ground, resulting from precipitation.

(34) *"Stormwater utility"* means the stormwater utility created by ordinance of the city to administer the stormwater management ordinance, and other stormwater rules and regulations adopted by the municipality.

(35) *"Structural BMPs"* means devices that are constructed to provide control of stormwater runoff.

(36) *"Surface water"* includes waters upon the surface of the earth in bounds created naturally or artificially including, but not limited to, streams, other water courses, lakes and reservoirs.

(37) *"Watercourse"* means a permanent or intermittent stream or other body of water, either natural or man-made, which gathers or carries surface water.

(38) *"Watershed"* means all the land area that contributes runoff to a particular point along a waterway.

Section 3. Land disturbance permits. (1). When required.

(a) Every person will be required to obtain a land disturbance permit from the _____ **(stormwater utility)** in the following cases:

(1) Land disturbing activity disturbs one (1) or more acres of land;

[NOTE: Municipalities have the option of generally requiring land disturbance permits for activities of less than one (1) acre. However, the general one (1) acre requirement is consistent with the size of the land disturbance for which a TDEC permit is also required.]

(2) Land disturbing activity of less than one (1) acre of land if such activity is part of a larger common plan of development that affects one (1) or more acre of land;

(3) Land disturbing activity of less than one (1) acre of land, if in the discretion of the _____ **(stormwater utility)** such activity poses a unique threat to water, or public health or safety;

(4) The creation and use of borrow pits.

(2). Building permit. No building permit shall be issued until the applicant has obtained a land disturbance permit where the same is required by this ordinance.

(3). Exemptions. The following activities are exempt from the permit requirement:

(a) Any emergency activity that is immediately necessary for the protection of life, property, or natural resources.

(b) Existing nursery and agricultural operations conducted as a permitted main or accessory use.

(c) Any logging or agricultural activity that is consistent with an approved farm conservation plan or a timber management plan prepared or approved by the _____**(appropriate federal or state agency)**.

(d) Additions or modifications to existing single family structures.

(4). Application for a land disturbance permit.

(a) Each application shall include the following:

(1) Name of applicant;

(2) Business or residence address of applicant;

(3) Name, address and telephone number of the owner of the property of record in the office of the assessor of property;

(4) Address and legal description of subject property including the tax reference number and parcel number of the subject property;

(5) Name, address and telephone number of the contractor and any subcontractor(s) who shall perform the land disturbing activity and who shall implement the erosion and sediment control plan;

(6) A statement indicating the nature, extent and purpose of the land disturbing activity including the size of the area for which the permit shall be applicable and a schedule for the starting and completion dates of the land disturbing activity.

(7) Where the property includes a sinkhole, the applicant shall obtain from the Tennessee Department of Environment and Conservation appropriate permits.

(8) The applicant shall obtain from any other state or federal agency any other appropriate environmental permits that pertain to the property. However, the inclusion of those permits in the application shall not foreclose the _____ (**stormwater utility**) from imposing additional development requirements and conditions, commensurate with this ordinance, on the development of property covered by those permits.

(b) Each application shall be accompanied by: (1) a sediment and erosion control plan as described in §5(5).

(2) A stormwater management plan as described in §5(4), providing for stormwater management during the land disturbing activity and after the activity has been completed.

(3) Each application for a land disturbance permit shall be accompanied by payment of land disturbance permit and other stormwater management fees, which shall be set by resolution or ordinance.

(5). Review and approval of application.

(a) The _____ **(stormwater utility)** will review each application for a land disturbance permit to determine its conformance with the provisions of this ordinance. Within ____ days after receiving an application, the _____ **(stormwater utility)** shall provide one of the following responses in writing:

(1) Approval of the permit application;

(2) Approval of the permit application, subject to such reasonable conditions as may be necessary to secure substantially the objectives of this ordinance, and issue the permit subject to these conditions; or

(3) Denial of the permit application, indicating the reason(s) for the denial.

(b) If the _____ **(stormwater utility)** has granted conditional approval of the permit, the applicant shall submit a revised plan that conforms to

the conditions established by the _____ **(stormwater utility)**. However, the applicant shall be allowed to proceed with his land disturbing activity so long as it conforms to conditions established by the _____ **(stormwater utility)**.

(c) No development plans will be released until the land disturbance permit has been approved.

(6). Permit duration.

Every land disturbance permit shall expire and become null and void if substantial work authorized by such permit has not commenced within one hundred eighty (180) calendar days of issuance, or is not complete within eighteen (18) months from the date of the commencement of construction.

(7). Notice of construction.

The applicant must notify the _____ **(stormwater utility)** ten (10) working days in advance of the commencement of construction. Regular inspections of the stormwater management system construction shall be conducted by the _____ **(stormwater utility)**. All inspections shall be documented and written reports prepared that contain the following information:

(1) The date and location of the inspection;

(2) Whether construction is in compliance with the approved stormwater management plan;

(3) Variations from the approved construction specifications;

(4) Any violations that exist.

(8). Performance bonds.

(a) The _____ **(stormwater utility)** may, at its discretion, require the submittal of a performance security or performance bond prior to issuance of a permit in order to ensure that the stormwater practices are installed by the permit holder as required by the approved stormwater management plan. The amount of the installation performance security or performance bond shall be the total estimated construction cost of the structural BMPs approved under the permit plus any reasonably foreseeable additional related costs, e.g., for damages or enforcement. [Or plus a certain percentage of the total estimated costs.] The performance security shall contain forfeiture provisions for failure to complete work specified in the stormwater management plan. The applicant shall provide an itemized construction cost estimate complete with unit prices which shall be subject to acceptance, amendment or rejection by the _____ (**stormwater utility**). Alternatively the _____ (**stormwater utility**) shall have the right to calculate the cost of construction cost estimates.

(b) The performance security or performance bond shall be released in full only upon submission of as-built plans and written certification by a registered professional engineer licensed to practice in Tennessee that the structural BMP has been installed in accordance with the approved plan and other applicable provisions of this ordinance. The _____ **(stormwater utility)** will make a final inspection of the structural BMP to ensure that it is in compliance with the

approved plan and the provisions of this ordinance. Provisions for a partial pro-rata release of the performance security or performance bond based on the completion of various development stages can be made at the discretion of the _____ **(stormwater utility)**.

Section 4. Waivers. (1). General. Every applicant shall provide for stormwater management as required by this ordinance, unless a written request is filed to waive this requirement. Requests to waive the stormwater management plan requirements shall be submitted to the _____ **(stormwater utility)** for approval.

(2). Conditions for waiver. The minimum requirements for stormwater management may be waived in whole or in part upon written request of the applicant, provided that at least one of the following conditions applies:

(a) It can be demonstrated that the proposed development is not likely to impair attainment of the objectives of this ordinance.

(b) Alternative minimum requirements for on-site management of stormwater discharges have been established in a stormwater management plan that has been approved by the _____ **(stormwater utility)**.

(c) Provisions are made to manage stormwater by an off-site facility. The off-site facility must be in place and designed to provide the level of stormwater control that is equal to or greater than that which would be afforded by on-site practices. Further, the facility must be operated and maintained by an entity that is legally obligated to continue the operation and maintenance of the facility.

(3). Downstream damage, etc. prohibited. In order to receive a waiver, the applicant must demonstrate to the satisfaction of the_____ **(stormwater utility)** that the waiver will not lead to any of the following conditions downstream:

(a) Deterioration of existing culverts, bridges, dams, and other structures;

(b) Degradation of biological functions or habitat;

(c) Accelerated streambank or streambed erosion or siltation;

(d) Increased threat of flood damage to public health, life or property.

(4). Land disturbance permit not to be issued where waiver requested. No land disturbance permit shall be issued where a waiver has been requested until the waiver is granted. If no waiver is granted, the plans must be resubmitted with a stormwater management plan.

Section 5. Stormwater system design and management standards. (1) Stormwater design or BMP manual.

(a) Adoption. The municipality adopts as its stormwater design and best management practices (BMP) manual the following publications, which are incorporated by reference in this ordinance as is fully set out herein:

(1) TDEC Sediment and Erosion Control Manual

(2) TDEC Manual for Post Construction

[NOTE: The municipality has great latitude with respect to the BMP manuals that it wishes to adopt. The above manuals are recommended but are not mandatory.]

(b) This manual includes a list of acceptable BMPs including the specific design performance criteria and operation and maintenance requirements for each stormwater practice. The manual may be updated and expanded from time to time, at the discretion of the governing body of the municipality, upon the

recommendation of the _____ **(stormwater utility)**, based on improvements in engineering, science, monitory and local maintenance experience. Stormwater facilities that are designed, constructed and maintained in accordance with these BMP criteria will be presumed to meet the minimum water quality performance standards.

(2). General performance criteria for stormwater management. Unless granted a waiver or judged by the _____ **(stormwater utility)** to be exempt, the following performance criteria shall be addressed for stormwater management at all sites:

(a) All site designs shall control the peak flow rates of stormwater discharge associated with design storms specified in this ordinance or in the BMP manual and reduce the generation of post construction stormwater runoff to pre-construction levels. These practices should seek to utilize pervious areas for stormwater treatment and to infiltrate stormwater runoff from driveways, sidewalks, rooftops, parking lots, and landscaped areas to the maximum extent practical to provide treatment for both water quality and quantity.

(b) To protect stream channels from degradation, specific channel protection criteria shall be provided as prescribed in the BMP manual.

(c) Stormwater discharges to critical areas with sensitive resources (i.e., cold water fisheries, shellfish beds, swimming beaches, recharge areas, water supply reservoirs) may be subject to additional performance criteria, or may need to utilize or restrict certain stormwater management practices.

(d) Stormwater discharges from "hot spots" may require the application of specific structural BMPs and pollution prevention practices.

(e) Prior to or during the site design process, applicants for land disturbance permits shall consult with the _____ **(stormwater utility)** to determine if they are subject to additional stormwater design requirements.

(f) The calculations for determining peak flows as found in the BMP manual shall be used for sizing all stormwater facilities.

(3). Minimum control requirements.

(a) Stormwater designs shall meet the multi-stage storm frequency storage requirements as identified in the BMP manual unless the _____ **(stormwater utility)** has granted the applicant a full or partial waiver for a particular BMP under § 4.

(b) If hydrologic or topographic conditions warrant greater control than that provided by the minimum control requirements, the _____ **(stormwater utility)** may impose any and all additional requirements deemed necessary to control the volume, timing, and rate of runoff.

(4). Stormwater management plan requirements. The stormwater management plan shall include sufficient information to allow the _____ **(stormwater utility)** to evaluate the environmental characteristics of the project site, the potential impacts of all proposed development of the site, both present and future, on the water resources, and the effectiveness and acceptability of the measures proposed for managing stormwater

generated at the project site. To accomplish this goal the stormwater management plan shall include the following:

(a) Topographic Base Map: A 1" = _____ topographic base map of the site which extends a minimum of___ feet beyond the limits of the proposed development and indicates:

(1) Existing surface water drainage including streams, ponds, culverts, ditches, sink holes, wetlands; and the type, size, elevation, etc., of nearest upstream and downstream drainage structures;

(2) Current land use including all existing structures, locations of utilities, roads, and easements;

(3) All other existing significant natural and artificial features;

(4) Proposed land use with tabulation of the percentage of surface area to be adapted to various uses; drainage patterns; locations of utilities, roads and easements; the limits of clearing and grading;

(5) Proposed structural BMPs;

(6) A written description of the site plan and justification of proposed changes in natural conditions may also be required.

(b) Calculations: Hydrologic and hydraulic design calculations for the pre-development and post-development conditions for the design storms specified in the BMP manual. These calculations must show that the proposed stormwater management measures are capable of controlling runoff from the site in

compliance with this ordinance and the guidelines of the BMP manual. Such calculations shall include:

(1) A description of the design storm frequency, duration, and intensity where applicable;

(2) Time of concentration;

(3) Soil curve numbers or runoff coefficients including assumed soil moisture conditions;

(4) Peak runoff rates and total runoff volumes for each watershed area;

(5) Infiltration rates, where applicable;

(6) Culvert, stormwater sewer, ditch and/or other stormwater conveyance capacities;

(7) Flow velocities;

(8) Data on the increase in rate and volume of runoff for the design storms referenced in the BMP manual; and

(9) Documentation of sources for all computation methods and field test results.

(c) Soils Information: If a stormwater management control measure depends on the hydrologic properties of soils (e.g., infiltration basins), then a soils report shall be submitted. The soils report shall be based on on-site boring logs or soil pit profiles and soil survey reports. The number and location of required soil borings or soil

pits shall be determined based on what is needed to determine the suitability and distribution of soil types present at the location of the control measure.

(d) Maintenance and Repair Plan: The design and planning of all stormwater management facilities shall include detailed maintenance and repair procedures to ensure their continued performance. These plans will identify the parts or components of a stormwater management facility that need to be maintained and the equipment and skills or training necessary. Provisions for the periodic review and evaluation of the effectiveness of the maintenance program and the need for revisions or additional maintenance procedures shall be included in the plan. A permanent elevation benchmark shall be identified in the plans to assist in the periodic inspection of the facility.

(e) Landscaping Plan: The applicant must present a detailed plan for management of vegetation at the site after construction is finished, including who will be responsible for the maintenance of vegetation at the site and what practices will be employed to ensure that adequate vegetative cover is preserved. Where it is required by the BMP, this plan must be prepared by a registered landscape architect licensed in Tennessee.

(f) Maintenance Easements: The applicant must ensure access to the site for the purpose of inspection and repair by securing all the maintenance easements needed. These easements must be binding on the current property owner and all subsequent owners of the property and must be properly recorded in the land record.

(g) Maintenance Agreement:

(1) The owner of property to be served by an on-site stormwater management facility must execute an inspection and maintenance agreement that shall operate as a deed restriction binding on the current property owner and all subsequent property owners.

(2) The maintenance agreement shall:

(a) Assign responsibility for the maintenance and repair of the stormwater facility to the owner of the property upon which the facility is located and be recorded as such on the plat for the property by appropriate notation.

(b) Provide for a periodic inspection by the property owner for the purpose of documenting maintenance and repair needs and ensure compliance with the purpose and requirements of this ordinance. The property owner will arrange for this inspection to be conducted by a registered professional engineer licensed to practice in the State of Tennessee who will submit a sealed report of the inspection to the _____ (**stormwater utility**). It shall also grant permission to the city to enter the property at reasonable times and to inspect the stormwater facility to ensure that it is being properly maintained.

(c) Provide that the minimum maintenance and repair needs include, but are not limited to: the removal of silt, litter and other debris, the cutting of grass, grass cuttings and vegetation removal, and the replacement of landscape vegetation, in detention and retention basins, and inlets and drainage pipes and any other stormwater facilities. It shall also provide that the property owner shall be responsible for additional maintenance and repair needs consistent with the needs and standards outlined in the BMP manual.

(d) Provide that maintenance needs must be addressed in a timely manner, on a schedule to be determined by the _____ (**stormwater utility**).

(e) Provide that if the property is not maintained or repaired within the prescribed schedule, the _____ (**stormwater utility**) shall perform the maintenance and repair at its expense, and bill the same to the property owner. The maintenance agreement shall also provide that the _____ stormwater utility's cost of performing the maintenance shall be a lien against the property.

(3) The municipality shall have the discretion to accept the dedication of any

existing or future stormwater management facility, provided such facility meets the requirements of this ordinance, and includes adequate and perpetual access and sufficient areas, by easement or otherwise, for inspection and regular maintenance. Any stormwater facility accepted by the municipality must also meet the municipality's construction standards and any other standards and specifications that apply to the particular stormwater facility in question.

(h) Sediment and Erosion Control Plans: The applicant must prepare a sediment and erosion control plan for all construction activities that complies with §5(5) below.

(5). Sediment and erosion control plan requirements. The sediment and erosion control plan shall accurately describe the potential for soil erosion and sedimentation problems resulting from land disturbing activity and shall explain and illustrate the measures that are to be taken to control these problems. The length and complexity of the plan is to be commensurate with the size of the project, severity of the site condition, and potential for off-site damage. The plan shall be sealed by a registered professional engineer licensed in the state of Tennessee. The plan shall also conform to the requirements found in the BMP manual, and shall include at least the following:

(a) Project Description - Briefly describe the intended project and proposed land disturbing activity including number of units and structures to be constructed and infrastructure required.

(b) A topographic map with contour intervals of five (5) feet or less showing present conditions and proposed contours resulting from land disturbing activity.

(c) All existing drainage ways, including intermittent and wet-weather. Include any designated floodways or flood plains.

(d) A general description of existing land cover. Individual trees and shrubs do not need to be identified.

(e) Stands of existing trees as they are to be preserved upon project completion, specifying their general location on the property. Differentiation shall be made between existing trees to be preserved, trees to be removed and proposed planted trees. Tree protection measures must be identified, and the diameter of the area involved must also be identified on the plan and shown to scale. Information shall be supplied concerning the proposed destruction of exceptional and historic trees in setbacks and buffer strips, where they exist. Complete landscape plans may be submitted separately. The plan must include the sequence of implementation for tree protection measures.

(f) Approximate limits of proposed clearing, grading and filling.

(g) Approximate flows of existing stormwater leaving any portion of the site.

(h) A general description of existing soil types and characteristics and any anticipated soil erosion and sedimentation problems resulting from existing characteristics.

(i) Location, size and layout of proposed stormwater and sedimentation control improvements.

(j) Proposed drainage network.

(k) Proposed drain tile or waterway sizes.

(l) Approximate flows leaving site after construction and incorporating water run-off mitigation measures. The evaluation must include projected effects on property adjoining the site and on existing drainage facilities and systems. The plan must address the adequacy of outfalls from the development: when water is concentrated, what is the capacity of waterways, if any, accepting stormwater off-site; and what measures, including infiltration, sheeting into buffers, etc., are going to be used to prevent the scouring of waterways and drainage areas off-site, etc.

(m) The projected sequence of work represented by the grading, drainage and sedimentation and erosion control plans as related to other major items of construction, beginning with the initiation of excavation and including the construction of any sediment basins or retention facilities or any other structural BMP's.

(n) Specific remediation measures to prevent erosion and sedimentation run-off. Plans shall include detailed drawings of all control measures used; stabilization measures including vegetation and non-vegetation measures, both temporary and permanent, will be detailed. Detailed construction notes and a maintenance schedule shall be included for all control measures in the plan.

(o) Specific details for: the construction of rock pads, wash down pads, and settling basins for controlling erosion; road access points; eliminating or keeping soil, sediment, and debris on streets and public ways at a level acceptable to the _____ **(stormwater utility)**. Soil, sediment, and debris brought

onto streets and public ways must be removed by the end of the work day by machine, broom or shovel to the satisfaction of the _____ **(stormwater utility)**. Failure to remove the sediment, soil or debris shall be deemed a violation of this ordinance.

(p) Proposed structures; location (to the extent possible) and identification of any proposed additional buildings, structures or development on the site.

(q) A description of on-site measures to be taken to recharge surface water into the ground water system through infiltration.

Section 6. Post Construction. (1). As built plans. All applicants are required to submit actual as built plans for any structures located on-site after final construction is completed. The plan must show the final design specifications for all stormwater management facilities and must be sealed by a registered professional engineer licensed to practice in Tennessee. A final inspection by the _____ **(stormwater utility)** is required before any performance security or performance bond will be released. The _____ **(stormwater utility)** shall have the discretion to adopt provisions for a partial pro-rata release of the performance security or performance bond on the completion of various stages of development. In addition, occupation permits shall not be granted until corrections to all BMP's have been made and accepted by the _____ **(stormwater utility)**.

(2). Landscaping and stabilization requirements.

(a) Any area of land from which the natural vegetative cover has been either partially or wholly cleared by development activities shall be revegetated according to a schedule approved by the _____ **(stormwater utility)**. The

following criteria shall apply to revegetation efforts:

(1) Reseeding must be done with an annual or perennial cover crop accompanied by placement of straw mulch or its equivalent of sufficient coverage to control erosion until such time as the cover crop is established over ninety percent (90%) of the seeded area.

(2) Replanting with native woody and herbaceous vegetation must be accompanied by placement of straw mulch or its equivalent of sufficient coverage to control erosion until the plantings are established and are capable of controlling erosion.

(3) Any area of revegetation must exhibit survival of a minimum of seventy-five percent (75%) of the cover crop throughout the year immediately following revegetation. Revegetation must be repeated in successive years until the minimum seventy-five percent (75%) survival for one (1) year is achieved.

(b) In addition to the above requirements, a landscaping plan must be submitted with the final design describing the vegetative stabilization and management techniques to be used at a site after construction is completed. This plan will explain not only how the site will be stabilized after construction, but who will be responsible for the maintenance of vegetation at the site and what practices will be employed to ensure that adequate vegetative cover is preserved.

(3). Inspection of stormwater management facilities. Periodic inspections of facilities shall be performed as provided for in §5(4)(g)(2)(b).

(4). Records of installation and maintenance activities. Parties responsible for the operation and maintenance of a stormwater management facility shall make records of the installation of the stormwater facility, and of all maintenance and repairs to the facility, and shall retain the records for at least___ years. These records shall be made available to the _____ **(stormwater utility)** during inspection of the facility and at other reasonable times upon request.

(5). Failure to meet or maintain design or maintenance standards. If a responsible party fails or refuses to meet the design or maintenance standards required for stormwater facilities under this ordinance, the _____**(stormwater utility)**, after reasonable notice, may correct a violation of the design standards or maintenance needs by performing all necessary work to place the facility in proper working condition. In the event that the stormwater management facility becomes a danger to public safety or public health, the _____(**stormwater utility**) shall notify in writing the party responsible for maintenance of the stormwater management facility. Upon receipt of that notice, the responsible person shall have___ days to effect maintenance and repair of the facility in an approved manner. In the event that corrective action is not undertaken within that time, the _____ **(stormwater utility)** may take necessary corrective action. The cost of any action by the _____ (**stormwater utility)** under this section shall be charged to the responsible party.

Section 7. Existing locations and developments. (1). Requirements for all existing locations and developments. The following requirements shall apply to all locations and development at which land disturbing activities have occurred previous to the enactment of this ordinance:

(a) Denuded areas must be vegetated or covered under the standards and guidelines specified in the BMP manual and on a schedule acceptable to the _____ **(stormwater utility)**.

(b) Cuts and slopes must be properly covered with appropriate vegetation and/or retaining walls constructed.

(c) Drainage ways shall be properly covered in vegetation or secured with rip-rapp, channel lining, etc., to prevent erosion.

(d) Trash, junk, rubbish, etc. shall be cleared from drainage ways.

(e) Stormwater runoff shall be controlled to the extent reasonable to prevent pollution of local waters. Such control measures may include, but are not limited to, the following:

(1) Ponds

(a) Detention pond

(b) Extended detention pond

(c) Wet pond

(d) Alternative storage measures

(2) Constructed wetlands

(3) Infiltration systems

(a) Infiltration/percolation trench

(b) Infiltration basin

(c) Drainage (recharge) well

(d) Porous pavement

(4) Filtering systems

(a) Catch basin inserts/media filter

(b) Sand filter

(c) Filter/absorption bed

(d) Filter and buffer strips

(5) Open channel

(a) swale

(2). Requirements for existing problem locations. The _____ (**stormwater utility**) shall in writing notify the owners of existing locations and developments of specific drainage, erosion or sediment problem affecting such locations and developments, and the specific actions required to correct those problems. The notice shall also specify a reasonable time for compliance.

(3). Inspection of existing facilities. The _____ **(stormwater utility)** may, to the extent authorized by state and federal law, establish inspection programs to verify that all stormwater management facilities, including those built before as well as after the adoption of this ordinance, are functioning within design limits. These inspection programs may be established on any reasonable basis, including but not limited to: routine inspections; random inspections; inspections based upon complaints or other notice of possible violations; inspection of drainage basins or areas identified as higher than typical sources of sediment or other contaminants or pollutants; inspections of businesses or industries of a type associated with higher than usual discharges of contaminants or pollutants or with discharges of a type which are more likely than the

typical discharge to cause violations of the municipality's NPDES stormwater permit; and joint inspections with other agencies inspecting under environmental or safety laws. Inspections may include, but are not limited to: reviewing maintenance and repair records; sampling discharges, surface water, groundwater, and material or water in drainage control facilities; and evaluating the condition of drainage control facilities and other BMPs.

(4). Corrections of problems subject to appeal. Corrective measures imposed by the stormwater utility under this section are subject to appeal under § 11 of this ordinance.

Section 8. Illicit discharges. (1). Scope. This section shall apply to all water generated on developed or undeveloped land entering the municipality's separate storm sewer system.

(2). Prohibition of illicit discharges. No person shall introduce or cause to be introduced into the municipal separate storm sewer system any discharge that is not composed entirely of stormwater. The commencement, conduct or continuance of any non-stormwater discharge to the municipal separate storm sewer system is prohibited except as described as follows:

(a) Uncontaminated discharges from the following sources:

(1) Water line flushing or other potable water sources,

(2) Landscape irrigation or lawn watering with potable water,

(3) Diverted stream flows,

(4) Rising ground water,

(5) Groundwater infiltration to storm drains,

(6) Pumped groundwater,

(7) Foundation or footing drains,

(8) Crawl space pumps,

(9) Air conditioning condensation,

(10) Springs,

(11) Non-commercial washing of vehicles,

(12) Natural riparian habitat or wet-land flows,

(13) Swimming pools (if dechlorinated - typically less than one PPM chlorine),

(14) Fire fighting activities, and

(15) Any other uncontaminated water source.

(b) Discharges specified in writing by the _____**(stormwater utility)** as being necessary to protect public health and safety.

(c) Dye testing is an allowable discharge if the _____**(stormwater utility)** has so specified in writing.

(3). Prohibition of illicit connections.

(a) The construction, use, maintenance or continued existence of illicit connections to the separate municipal storm sewer system is prohibited.

(b) This prohibition expressly includes, without limitation, illicit connections made in the past, regardless of whether the connection was permissible under law or practices applicable or prevailing at the time of connection.

(4). Reduction of stormwater pollutants by the use of best management practices. Any person responsible for a property or premises, which is, or may be, the source of an illicit

discharge, may be required to implement, at the person's expense, the BMP's necessary to prevent the further discharge of pollutants to the municipal separate storm sewer system. Compliance with all terms and conditions of a valid NPDES permit authorizing the discharge of stormwater associated with industrial activity, to the extent practicable, shall be deemed compliance with the provisions of this section.

(5). Notification of spills. Notwithstanding other requirements of law, as soon as any person responsible for a facility or operation, or responsible for emergency response for a facility or operation has information of any known or suspected release of materials which are resulting in, or may result in, illicit discharges or pollutants discharging into stormwater, the municipal separate storm sewer system, the person shall take all necessary steps to ensure the discovery, containment, and cleanup of such release. In the event of such a release of hazardous materials the person shall immediately notify emergency response agencies of the occurrence via emergency dispatch services. In the event of a release of non-hazardous materials, the person shall notify the _____ **(stormwater utility)** in person or by telephone or facsimile no later than the next business day. Notifications in person or by telephone shall be confirmed by written notice addressed and mailed to the _____ **(stormwater utility)** within three (3) business days of the telephone notice. If the discharge of prohibited materials emanates from a commercial or industrial establishment, the owner or operator of such establishment shall also retain an on-site written record of the discharge and the actions taken to prevent its recurrence. Such records shall be retained for at least _____ years.

Section 9. Enforcement

(1). Enforcement authority. The director of the _____ (**stormwater utility**) or his designees shall have the authority to issue notices of violation and citations, and to impose the civil penalties provided in this section.

(2). Notification of violation.

(a) Written Notice. Whenever the director of the _____ **(stormwater utility)** finds that any permittee or any other person discharging stormwater has violated or is violating this ordinance or a permit or order issued hereunder, the director may serve upon such person written notice of the violation. Within ten (10) days of this notice, an explanation of the violation and a plan for the satisfactory correction and prevention thereof, to include specific required actions, shall be submitted to the director. Submission of this plan in no way relieves the discharger of liability for any violations occurring before or after receipt of the notice of violation.

(b) Consent Orders. The director is empowered to enter into consent orders, assurances of voluntary compliance, or other similar documents establishing an agreement with the person responsible for the noncompliance. Such orders will include specific action to be taken by the person to correct the noncompliance within a time period also specified by the order. Consent orders shall have the same force and effect as administrative orders issued pursuant to paragraphs (d) and (e) below.

(c) Show Cause Hearing. The director may order any person who violates this ordinance or permit or order issued hereunder, to show cause why a proposed enforcement action should not be taken. Notice shall be served on the person specifying the time and place for the meeting, the proposed enforcement action and the reasons for such action, and a request that the violator show cause why this proposed enforcement action should not be taken. The notice of the meeting shall be served personally or by registered or certified mail (return receipt requested) at least ten (10) days prior to the hearing.

(d) Compliance Order. When the director finds that any person has violated or continues to violate this ordinance or a permit or order issued thereunder, he may issue an order to the violator directing that, following a specific time period, adequate structures, devices, be installed or procedures implemented and properly operated. Orders may also contain such other requirements as might be reasonably necessary and appropriate to address the noncompliance, including the construction of appropriate structures, installation of devices, self-monitoring, and management practices.

(e) Cease and Desist Orders. When the director finds that any person has violated or continues to violate this ordinance or any permit or order issued hereunder, the director may issue an order to cease and desist all such violations and direct those persons in noncompliance to:

(1) Comply forthwith; or

(2) Take such appropriate remedial or preventive action as may be needed to properly address a continuing or threatened violation, including halting operations and terminating the discharge.

(3). Conflicting standards. Whenever there is a conflict between any standard contained in this ordinance and in the BMP manual adopted by the municipality under this ordinance, the strictest standard shall prevail.

Section 10. Penalties. (1). Violations. Any person who shall commit any act declared unlawful under this ordinance, who violates any provision of this ordinance, who violates the provisions of any permit issued pursuant to this ordinance, or who fails or refuses to comply with any lawful communication or notice to abate or take corrective action by the _____ (**stormwater utility)**, shall be guilty of a civil offense.

(2). Penalties. Under the authority provided in Tennessee Code Annotated §68-221-1106, the municipality declares that any person violating the provisions of this ordinance may be assessed a civil penalty by the _____ **(stormwater utility)** of not less than fifty dollars ($50.00) and not more than five thousand dollars ($5,000.00) per day for each day of violation. Each day of violation shall constitute a separate violation.

[NOTE: In City of Chattanooga v. Davis, 54 S.W. 3d 248 (Tenn. 2001), the Tennessee Supreme Court held that municipal civil penalties or fines in excess of $50 violate Article VI, § 14, of the Tennessee Constitution, if their purpose is punitive rather than remedial. Article VI, § 14 of the Tennessee Constitution provides that, "No fine shall be laid on any citizen of this state that shall exceed Fifty Dollars, unless it shall be assessed by a jury of his peers...." The determination of whether a civil penalty or fine is punitive or remedial is determined on a case by case basis by a "totality of circumstances." The distinction between punitive and a remedial civil penalties or fines is so difficult to draw that as a practical matter, most municipal courts are not asked to levy, or do not levy, civil penalties or fines of over $50.

However, it is questionable whether City of Chattanooga v. Davis applies to administrative penalties that exceed $50. The Chancery Court for Davidson County in Dickson v. State, No. 00-2823-1, filed December 5, 2001, held that the answer was no with respect to two fines totaling $15,000 levied by the Tennessee Petroleum Underground Storage Tank Board Petroleum Tank Storage Board. It reasoned that Davis applied only to civil penalties levied by a court, and that an administrative agency is not a court. Tennessee Code Annotated, § 68-221-1106 appears to contemplate that the civil penalty for stormwater ordinance violations be levied by a municipal official or entity rather than a court.]

(3). Measuring civil penalties. In assessing a civil penalty, the director of the _____ (**stormwater utility**) may consider:

(a) The harm done to the public health or the environment;

(b) Whether the civil penalty imposed will be a substantial economic deterrent to the illegal activity;

(c) The economic benefit gained by the violator;

(d) The amount of effort put forth by the violator to remedy this violation;

(e) Any unusual or extraordinary enforcement costs incurred by the municipality;

(f) The amount of penalty established by ordinance or resolution for specific categories of violations; and

(g) Any equities of the situation which outweigh the benefit of imposing any penalty or damage assessment.

(4). Recovery of damages and costs. In addition to the civil penalty in subsection (2) above, the municipality may recover; (a) all damages proximately caused by the violator to the

municipality, which may include any reasonable expenses incurred in investigating violations of, and enforcing compliance with, this ordinance, or any other actual damages caused by the violation.

(b) The costs of the municipality's maintenance of stormwater facilities when the user of such facilities fails to maintain them as required by this ordinance.

(5). Other remedies. The municipality may bring legal action to enjoin the continuing violation of this ordinance, and the existence of any other remedy, at law or equity, shall be no defense to any such actions.

(6). Remedies cumulative. The remedies set forth in this section shall be cumulative, not exclusive, and it shall not be a defense to any action, civil or criminal, that one (1) or more of the remedies set forth herein has been sought or granted.

Section 11. Appeals. Pursuant to Tennessee Code Annotated §68-221-1106(d), any person aggrieved by the imposition of a civil penalty or damage assessment as provided by this ordinance may appeal said penalty or damage assessment to the municipality's governing body.

(1). Appeals to be in writing. The appeal shall be in writing and filed with the municipal recorder or clerk within fifteen (15) days after the civil penalty and/or damage assessment is served in any manner authorized by law.

(2). Public hearing. Upon receipt of an appeal, the municipality's governing body shall hold a public hearing within thirty (30) days. Ten (10) days prior notice of the time, date, and location of said hearing shall be published in a daily newspaper of general circulation. Ten (10) days notice by registered mail shall also be provided to the aggrieved party, such notice to be sent to the address provided by the aggrieved party at the time of appeal. The

decision of the governing body of the municipality shall be final.

(3). Appealing decisions of the municipality's governing body. Any alleged violator may appeal a decision of the municipality's governing body pursuant to the provisions of Tennessee Code Annotated, title 27, chapter 8.

Appendix C

Model Stormwater Utility Ordinance

MODEL STORMWATER UTILITY ORDINANCE

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MODEL STORMWATER UTILITY ORDINANCE

ORDINANCE NO.

WHEREAS, The Federal Clean Water Act, 33 U.S.C. 1251 et seq., requires certain political entities, such as the city, to implement stormwater management programs within prescribed time frames, and the Environmental Protection Agency, pursuant to the Federal Clean Water Act, 33 U.S.C. 1251 et seq., has published rules for stormwater outfall permits;

WHEREAS, Tennessee Code Annotated, § 68-221-1101, provides that the purpose of the stormwater management statute is to facilitate municipal compliance with the Water Quality Act of 1977, and applicable EPA regulations, particularly those arising from § 405 of the Water Quality Act of 1987, and § 402(p) of the Clean Water Act of 1977, and to enable municipalities to regulate stormwater discharges, establish a system of drainage facilities, construct and operate a system of stormwater management and flood control facilities, and to "fix and require payment of fees for the privilege of discharging stormwater,"

WHEREAS, Tennessee Code Annotated, § 68-221-1105 provides that among other powers municipalities have with respect to stormwater facilities, is the power by ordinance or resolution to:

(1) Exercise general regulation over the planning, location, construction, and operation and maintenance of stormwater facilities in the municipality, whether or not owned and operated by the municipality;

(2) Adopt any rules and regulations deemed necessary to accomplish the purposes of this statute, including the adoption of a system of fees for services and permits;

(3) Establish standards to regulate the quantity of stormwater discharged and to regulate stormwater contaminants as may be necessary to protect water quality;

(4) Review and approve plans and plats for stormwater management in proposed subdivisions or commercial developments;

(5) Issue permits for stormwater discharges, and for the construction, alteration, extension, or repair of stormwater facilities;

(6) Suspend or revoke permits when it is determined that the permittee has violated any applicable ordinance, resolution, or condition of the permit;

(7) Regulate and prohibit discharges into stormwater facilities of sanitary, industrial, or commercial sewage or waters that have otherwise been contaminated;

(8) Expend funds to remediate or mitigate the detrimental effects of contaminated land or other sources of stormwater contamination, whether public or private; and

WHEREAS, The city desires to develop a stormwater utility to be responsible for the operation, construction and maintenance of stormwater facilities; for stormwater system planning, and for review of stormwater development plans for compliance with stormwater management codes.

NOW THEREFORE, BE IT ENACTED BY THE _____OF THE CITY OF _____, TENNESSEE, THAT:

Section 1. Legislative findings and policy. The _____ _____ (governing body of the city) finds, determines and declares that the stormwater system which provides for the collection, treatment, storage and disposal of stormwater provides benefits and services to all property within the incorporated city limits.

Such benefits include, but are not limited to: the provision of adequate systems of collection, conveyance, detention, treatment and release of stormwater; the reduction of hazards to property and life resulting from stormwater runoff; improvements in general health and welfare through reduction of undesirable stormwater conditions; and improvements to the water quality in the stormwater and surface water system and its receiving waters.

Section 2. Creation of stormwater utility. For those purposes of the Federal Clean Water Act and of Tennessee Code Annotated, § 68-221-1101 et seq., there is created a stormwater utility which shall consist of a manager or director and such staff as the municipality's governing body shall authorize.

> [NOTE: Organizational variations are possible depending upon the wants, needs and capabilities of individual municipalities. For example, the stormwater utility could be made a stand-alone department, or placed under an existing department].

The stormwater utility, under the legislative policy, supervision and control of the governing body of the city, shall:

(1) Administer the acquisition, design, construction, maintenance and operation of the stormwater utility system, including capital improvements designated in the capital improvement program;

(2) Administer and enforce this ordinance and all regulations and procedures adopted relating to the design, construction, maintenance, operation and alteration of the utility stormwater system, including, but not limited to, the quantity, quality and/or velocity of the stormwater conveyed thereby;

(3) Advise the municipality's governing body and other city departments on matters relating to the utility;

(4) Prepare and revise a comprehensive drainage plan for adoption by the municipality's governing body;

(5) Review plans and approve or deny, inspect and accept extensions and connections to the system;

(6) Enforce regulations to protect and maintain water quality and quantity within the system in compliance with water quality standards established by state, regional and/or federal agencies as now adopted or hereafter amended;

(7) Annually analyze the cost of services and benefits provided, and the system and structure of fees, charges, civil penalties and other revenues of the utility.

Section 3. Definitions. For the purpose of this ordinance, the following definitions shall apply: Words used in the singular shall include the plural, and the plural shall include the singular; words used in the present tense shall include the future tense. The word "shall" is mandatory and not discretionary. The word "may" is permissive. Words not defined in this section shall be construed to have the meaning given by common and ordinary use as defined in the latest edition of Webster's Dictionary.

(1) "Base rate" means the stormwater user's fee for a detached single family residential property in the city.

(2) "Construction" means the erection, building, acquisition, alteration, reconstruction, improvement or extension of stormwater facilities; preliminary planning to determine the economic and engineering feasibility of stormwater facilities; the engineering, architectural, legal, fiscal and economic investigations and studies, surveys, designs, plans, working drawings, specifications, procedures, and other action necessary in the construction of

stormwater facilities; and the inspection and supervision of the construction of stormwater facilities;

(3) "Developed property" means real property which has been altered from its natural state by the creation or addition of impervious areas, by the addition of any buildings, structures, pavement or other improvements.

(4) "Equivalent residential unit" or "ERU" means the average square footage of a detached single family residential property determined pursuant to this ordinance.

(5) "Exempt property" means all properties of the federal, state, county, and city governments, and any of their divisions or subdivisions, and property that does not discharge stormwater runoff into the stormwater or flood control facilities of the municipality.

(6) "Fee" or "Stormwater user's fee" means the charge established under this ordinance and levied on owners or users of parcels or pieces of real property to fund the costs of stormwater management and of operating, maintaining, and improving the stormwater system in the municipality. The stormwater user's fee is in addition to any other fee that the municipality has the right to charge under any other rule or regulation of the municipality.

(7) "Fiscal year" means July 1 of a calendar year to June 30 of the next calendar year, both inclusive.

(8) "Impervious surface" means a surface which is compacted or covered with material that is resistant to infiltration by water, including, but not limited to, most conventionally surfaced streets, roofs, sidewalks, patios, driveways, parking lots, and any other oiled, graveled, graded, compacted, or any other surface which impedes the natural infiltration of surface water.

(9) “Impervious surface area” means the number of square feet of horizontal surface covered by buildings, and other impervious surfaces. All building measurements shall be made between exterior faces of walls, foundations, columns or other means of support or enclosure.

(10) “Other developed property” means developed property other than single-family residential property. Such property shall include, but not be limited to, commercial properties, industrial properties, parking lots, hospitals, schools, recreational and cultural facilities, hotels, offices, and churches.

(11) “Person” means any and all persons, natural or artificial, including any individual, firm or association, and any municipal or private corporation organized or existing under the laws of this or any other state or country.

(12) “Property owner” means the property owner of record as listed in the county’s assessment roll. A property owner includes any individual, corporation, firm, partnership, or group of individuals acting as a unit, and any trustee, receiver, or personal representative.

(13) “Single family residential property” means a developed property which serves the primary purpose of providing a permanent dwelling unit to a single family. A single family detached dwelling or a townhouse containing an accessory apartment or second dwelling unit is included in this definition.

(14) "Stormwater" means stormwater runoff, snow melt runoff, surface runoff, street wash waters related to street cleaning or maintenance, infiltration, and drainage.

(15) "Stormwater management fund" or “fund” means the fund created by this ordinance to operate, maintain, and improve the city’s stormwater system.

(16) “Stormwater management” means the planning, design, construction, regulation,

improvement, repair, maintenance, and operation of facilities and programs relating to water, flood plains, flood control, grading, erosion, tree conservation, and sediment control.

(17) "Surface water" includes waters upon the surface of the earth in bounds created naturally or artificially including, but not limited to, streams, other water courses, lakes and reservoirs.

(18) “User” shall mean the owner of record of property subject to the stormwater user’s fee imposed by this ordinance.

Section 4. Funding of stormwater utility. Funding for the stormwater utility’s activities may include, but not be limited to, the following:

(1) Stormwater user’s fees.

(2) Civil penalties and damage assessments imposed for or arising from the violation of the city’s stormwater management ordinance.

(3) Stormwater permit and inspection fees.

(4) Other funds or income obtained from federal, state, local, and private grants, or revolving funds, and from the Local Government Public Obligations Act of 1986 (Tennessee Code Annotated, title 9, chapter 21).

To the extent that the stormwater drainage fees collected are insufficient to construct needed stormwater drainage facilities, the cost of the same may be paid from such city funds as may be determined by the municipality’s governing body.

Section 5. Stormwater fund. All revenues generated by or on behalf of the stormwater utility shall be deposited in a stormwater utility fund and used exclusively for the stormwater utility.

Section 6. Operating budget. The municipality's governing body shall adopt an operating budget for the stormwater utility each fiscal year. The operating budget shall set forth for such fiscal year the estimated revenues and the estimated costs for operations and maintenance, extension and replacement and debt service.

Section 7. Stormwater user's fees established. There shall be imposed on each and every developed property in the city, except exempt property, a stormwater user's fee, which shall be set from time to time by ordinance or resolution, and in the manner and amount prescribed by this ordinance.

Prior to establishing or amending user's fees, the municipality shall advertise its intent to do so by publishing notice in a newspaper of general circulation in the city at least thirty (30) days in advance of the meeting of the municipality's governing body which shall consider the adoption of the fee or its amendment.

Section 8. Equivalent residential unit (ERU). (1) Establishment. There is established for purposes of calculating the stormwater user's fee the equivalent residential unit (ERU).

(2) Definition. The ERU is the average square footage of a detached single family residential property.

(3) Setting the ERU. The ERU shall be set by the municipality's governing body from time to time by ordinance or resolution.

(4) Source of ERU. The municipality's governing body shall have the discretion to determine the source of the data from which the ERU is established, taking into consideration the general acceptance and use of such source on the part of other stormwater systems, and the reliability and general accuracy of the source. The municipality's governing body shall have the discretion to determine the impervious surface area of other developed property through property tax assessor's rolls or site examination, mapping information, aerial photographs, and other reliable information.

Section 9. Property classification for stormwater user's fee. (1) Property classifications. For purposes of determining the stormwater user's fee, all properties in the city are classified into one of the following classes:

(a) Single family residential property;

(b) Other developed property;

(c) Exempt property.

(2) Single family residential fee. The municipality's governing body finds that the intensity of development of most parcels of real property in the municipality classified as single family residential is similar and that it would be excessively and unnecessarily expensive to determine precisely the square footage of the improvements (such as buildings, structures, and other impervious areas) on each such parcel. Therefore, all single family residential properties in the city shall be charged a flat stormwater management fee, equal the base rate, regardless of the size of the parcel or the improvements.

(3) Other developed property fee. The fee for other developed property (i.e., non-single-family residential property) in the municipality shall be the base rate multiplied by the numerical factor obtained by dividing the total impervious area (square feet) of the property by one ERU. The impervious surface area for other developed property is the square footage for the buildings and other improvements on the property. The minimum stormwater management fee for other developed property shall equal the base rate for single family residential property.

(4) Exempt property. There shall be no stormwater user's fee for exempt property.

[Note: Appendix A contains an outline of how to calculate the stormwater user's fee based on this ordinance.

Various methods and formulas for setting the ERU are used in the United States. They range from simple to complicated, generally depending on how many and what types of property classifications, and which types of measurement to determine impervious areas, a municipality wishes to use. The method contained in this ordinance is among the simplest, and is based on two categories of developed property: single family residential, and all other developed property. An outstanding publication that lays out the various methods, and their advantages and disadvantages, is **Establishing a Stormwater Utility in Florida**, published by the Florida Association of Stormwater Utilities. Although this publication is obviously related to stormwater utilities in that state, it is highly useful for stormwater related issues in any state. MTAS has a copy of the publication. It is also available on the internet and from the publisher.]

Section 10. Base Rate. The municipality's governing body shall, by ordinance or resolution, establish the base rate for the stormwater user's fee. The base rate shall be calculated to insure adequate revenues to fund the costs of stormwater management and to provide for the operation, maintenance, and capital improvements of the stormwater system in the city.

Section 11. Adjustments to stormwater user's fees. The stormwater utility shall have the right on its own initiative to adjust upward or downward the stormwater user's fees with respect to any property, based on the approximate percentage on any significant variation in the volume or rate of stormwater, or any significant variation in the quality of stormwater, emanating from the property, compared to other similar properties. In making determinations of the

similarity of property, the stormwater utility shall take into consideration the location, geography, size, use, impervious area, stormwater facilities on the property, and any other factors that have a bearing on the variation.

Section 12. Property owners to pay charges. The owner of each non-exempt lot or parcel shall pay the stormwater user's fees and charges as provided in this ordinance.

> [NOTE: This section makes property owners liable for the stormwater user's fees. See Appendix B for an analysis of the question of whether the "user" is the land owner or the occupant of the property within the meaning of Tennessee Code Annotated, § 68-221-1107(a). There are other alternatives:
>
> Make utility customers liable for the stormwater user's fee, and collect the fee from those customers in the same manner as utility bills are collected. There are administrative difficulties inherent in that alternative in the case of municipalities that provide only some or no utilities.
>
> Make occupants of property liable for the stormwater user's fees. There are also administrative difficulties inherent in this alternative where the municipality has no efficient method of determining the occupants of structures, such as in the case where multiple tenants are served by a single utility meter, and in the case of multi-family dwellings generally.
>
> In addition, any alternative where occupants other than the land owner are made liable for the stormwater user's fee requires that the formulae for calculating the stormwater user's fee take into account the proportionate allocation of the fee among multiple tenants.]

Section 13. Billing procedures and penalties for late payment. (1) Rate and collection schedule. The stormwater user's fee must be set at a rate, and collected on a schedule, established by ordinance or resolution.

(2) Delinquent bills. The stormwater user's fee shall be paid in person or by mail at _____ and shall become delinquent as of _____ days following the billing. Any unpaid stormwater user's fee shall bear interest at the legal rate if it remains unpaid after _____ days following the billing.

(3) Penalties for late payment. Stormwater user's fees shall be subject to a late fee established by ordinance or resolution. The municipality shall be entitled to recover attorney's

fees incurred in collecting delinquent drainage fees. Any charge due under this ordinance which shall not be paid may be recovered at law by the municipality.

[NOTE: Tennessee Attorney General's Opinion 93-59, opines that it is not legal for a municipality to bill the stormwater user's fee on property tax bills or to make such fees a lien on property.]

(4) Mandatory statement. Pursuant to Tennessee Code Annotated § 68-221-1112, each bill that shall contain stormwater user's fees shall contain the following statement in bold:

THIS TAX HAS BEEN MANDATED BY CONGRESS.

[NOTE: Notwithstanding the statement required to be contained on the stormwater user's fee bill, the fee is probably not a tax. The distinction between fees and taxes with respect to the stormwater user's fee authorized by Tennessee Code Annotated, § 68-221-1107(a) are outlined in Tennessee Attorney's General Opinions 93-59 and 94-039.]

Section 14. Appeals of fees. (1) Generally. Any person who disagrees with the calculation of the stormwater user's fee, as provided in this ordinance, or who seeks a stormwater user's fee adjustment based upon stormwater management practices, may appeal such fee determination to the stormwater utility within thirty (30) days from the date of the last bill containing stormwater user's fees charges. Any appeal shall be filed in writing and shall state the grounds for the appeal. The stormwater utility director may request additional information from the appealing party.

(2) Adjustments. Stormwater user's fee adjustments for stormwater management practices may be considered for: reductions in runoff volume including discharge to a non-city drainage system; and properly designed constructed and maintained existing retention facilities, i.e. evaporation and recharge. Based upon the information provided by the utility and the appealing party, the stormwater utility shall make a final calculation of the stormwater drainage fee. The stormwater utility shall notify the parties, in writing, of its decision.

APPENDIX A

Calculating Stormwater User Fees

Calculating Stormwater User Fees can be done in a simple, equitable manner. The annual budget of the Stormwater Utility is divided by the total number of Equivalent Residential Units (ERU's) in the Stormwater System limits. Division of the result by 12 would yield the monthly fee per ERU. An Equivalent Residential Unit is based on the average square footage of a detached single residential family property. This average can be obtained from a variety of sources. If the average is not available through your tax assessor or another internal department, averages may be obtained from the U.S. Census Bureau, your local Area Association of Realtors, or some other credible source. Each detached single residential family property would be one (1) ERU. Other developed proposer users would divide their total amount of impervious surface area (in square feet) by the number of square feet in an ERU, to get the number of ERU's for that property. The sum of all other developed property ERU's and single family residential ERU's would be the total number of ERU's.

Annual Budget. The annual costs for the storm drainage system includes permitting, maintaining, planning, designing, reconstructing, constructing, environmentally restoring, regulating, testing, inspection of the system, management and administration, and the establishment of a reserve balance.

Equivalent Residential Unit (ERU). The average square footage of a single family residential property is equivalent to one ERU.*

Total ERU's. The Total ERU's within the limits of the stormwater utility is calculated according to the following formula:

Total ERU's = Other Developed Property ERU's + Single Family Residential ERU's

Single Family Residential User Fee. The fee that residential users within the limits of the stormwater utility pay for their share of the annual budget. The fee is calculated according to the following formula:

Single Family Residential User Fee = Annual Budget ÷ Total ERU's within Stormwater Utility limits

This number should be divided by 12 to establish the monthly User Fee:

Single Family Residential User Fee ÷ 12 = Monthly Single Family Residential User Fee

Other Developed Property User Fee. The fee that other developed property users within the limits of the stormwater utility pay for their share of the annual budget. The fee is calculated

according to the following formula:

Other Developed Property ERU's = Impervious Surface Area square feet ÷ ERU square feet

Other Developed Property User Fee = Single Family Residential User Fee x Other Developed Property ERU's

Other Developed Property User Fee ÷ 12 = Monthly Other Developed Property User Fee

Example: VolVegas Stormwater Utility Department has an annual budget of $350,000. There are 10,000 homes in VolVegas, an apartment complex, Maxwell House Apartments, with a total impervious surface area of 5 acres, or 217,800 square feet (sq. ft.), a motel, Red Lite Inn, with a total impervious surface area of 2 acres, or 87,120 square feet, GoodDay Tire and Rubber Company with a total impervious surface area of 15 acres, or 653,400 square feet, and a SuperWallyWorld with a total impervious surface area of 10 acres, or 435,600 square feet. Per the VolVegas Area Association of Realtors, the average detached single family residential property has 1,800 square feet.

1 ERU = 1,800 square feet

Single Family Residential ERU's = 10,000 ERU's

Other Developed Property ERU's = $\frac{(217{,}800 + 87{,}120 + 653{,}400 + 435{,}600 \text{ sf})}{1{,}800 \text{ sq ft}} = \frac{1{,}393{,}920 \text{ sf}}{1{,}800 \text{ sq ft}}$

= 774 ERU's

Total ERU's = 774 Other Developed Property ERU's + 10,000 Single Family Residential ERU's = 10,774 ERU's

Single Family Residential User Fee = $350,000 annually ÷ 10,774 ERU's = $32.49 annually/ ERU

OR

($32.49 annually/ERU) ÷ (12 mo./year) = **$2.71 monthly/ERU = Monthly Single Family Residential User Fee**

Maxwell House Apartments:

Maxwell House Apartment's ERU's: 217,800 sq ft ÷ 1,800 sq ft/ERU = 121 ERU's

Maxwell House Apartment's Monthly User Fee:

$2.71 monthly/ERU x 121 ERU's = **$327.91= Maxwell House Apartment's Monthly User Fee**

Red Lite Inn:

Red Lite Inn's ERU's: 87,120 sq ft ÷ 1,800 sq ft/ERU = 48.4 ERU's

Red Lite Inn's Monthly User Fee:

$2.71 monthly/ERU x 48.4 ERU's = **$131.16 = Red Lite Inn's Monthly User Fee**

Super WallyWorld:

Super WallyWorld's ERU's: 435,600 sq ft ÷ 1,800 sq ft/ERU = 242 ERU's

Super WallyWorld's Monthly User Fee:

$2.71 monthly/ERU x 242 ERU's = **$655.82 = Super WallyWorld's Monthly User Fee**

GoodDay Tire and Rubber Company:

GoodDay Tire and Rubber Company's ERU's = 653,400 sq ft ÷ 1,800 sq ft/ERU = 363 ERU's

GoodDay Tire and Rubber Company's Monthly User Fee:

$2.71 monthly/ERU x 363 ERU's = **$983.73 = GoodDay Tire and Rubber Company's Monthly User Fee**

** The average square footage of a single family residential property should be determined by a recognized source.*

For example:

The U.S. Census Bureau reports the median square footage in the South is 1,648 square feet.

Or:

In Jackson, Tennessee, the average square footage for all such properties sold in 2001 was 1,932 square feet, according to the Jackson Area Association of Realtors®.

A comparable source should be used for setting ERU square footage.

APPENDIX B

Tennessee Code Annotated, § 68-221-1107(a), provides that, "All municipalities constructing, operating, or maintaining stormwater or flood control facilities are authorized to establish a graduated stormwater user's fee which may be assessed and collected from each *user* of the stormwater facilities provided by the municipality...." It does not define "user," providing only that, "To ensure a proportionate distribution of all costs to each user or user class, the user's contribution shall be based on factors such as the amount of impervious area utilized by the user, the water quality of user's stormwater runoff or the volume or rate of stormwater runoff...." It also provides that:

- "Users whose stormwater runoff is not discharged into or through the stormwater and/or flood control facilities of the municipality shall be exempted from the payment of the graduated stormwater user fee authorized by this section."

- "The fee structure shall provide adjustments for users who construct facilities to retain and control the quantity of stormwater runoff."

Generally, the term "user" with respect to utilities probably means the beneficial user of the utility rather than the title holder of the property. In Village of Sauget v. Cohn, 610 N.E.2d 104 (Ill. App. 5th Dist. 1993), an ordinance required that the "user" pay sewer charges, but did not define the term "user." The Court held that the title holder of the property was not the "user," reasoning that:

> This is consistent with the Black's Law Dictionary definition of user. Black's defines a user as "[t]he actual exercise or enjoyment of any right, property, drugs, franchise, etc"....Because the defendant [the title holder of the property] is not the person who receives the services, he is not the person who actually exercises or enjoys the benefits provided by American Bottoms. He is, at most, an indirect beneficiary of the services, i.e., his properties are more marketable because they have indoor plumbing." [At 108]

It is not clear from Tennessee Code Annotated, § 68-221-1107(a) that the municipality can make the landowner rather than the tenant or occupant of the property a "user" for the purposes of the stormwater user's fee. Arguably it limits the city to the actual or beneficial user. Tennessee Code Annotated, § 68-221-1107(b), appears by implication to support that conclusion because it provides that the stormwater utility is authorized to enter into a contract with any other public or private utility (except an electrical cooperative organized under the Electric Cooperative Law) or city or town to bill and collect stormwater fees as a designated item on its utility bill, and to discontinue utility services where the stormwater utility fee is not paid. In most cases any utility bills would be in the name of the actual or beneficial user or users of the property. But that
statute may reflect only a method for municipalities to collect stormwater management fees through various utility entities rather than an implication that cities must impose stormwater

management fees on the beneficial users of the stormwater utility as opposed to land owners.

An argument can also be made that Tennessee Code Annotated, § 68-221-1107(a), authorizes a city to name the property owner the "user" within the meaning of that statute. A number of cases from other jurisdictions declare that utility user fees differ from taxes in that the payment of utility service fees is voluntary while the payment of taxes is involuntary. [See Pinellas County v. State, 776 So.2d 262 (Fla. 2001); City of Gary v. Indiana Bell Telephone Co., Inc., 732 N.E.2d 149 (Ind. 2000); Bolt v. City of Lansing, 587 N.W.2d 264 (Mich. 1998); State v. City of Port Orange, 650 So.2d 1 (Fla. 1994).] But our sister State of Arkansas has held that mandatory fees levied on property owners under the state's police powers are still user fees rather than taxes. [See Holman v. City of Dierks, 233 S.W.2d 392 (Ark. 1950); Vandiver v. Washington County, 628 S.W.2d 1 (Ark. 1982).]

In either case, a person who obtains or continues electric, water, even sewer, or most other utility services is a voluntary "user" of the service to a degree that does not typically apply to the user of a stormwater utility. In providing that the "user's contribution [fee] shall be based on factors such as the amount of *impervious areas utilized by the user*, the water quality of user's stormwater runoff or the volume or rate of stormwater runoff," Tennessee Code Annotated, § 68-221-1107, contemplates that virtually all developed property will be subject to a mandatory stormwater management fee. In addition, the stormwater user's fee connected to the impervious areas of land under that statute is more closely tied to the land than is the fee for most other utility services. The stormwater utility service is always "on" with respect to the impervious surface of the land no matter who is the beneficial user of other utility services that serve the land. The decision to develop the land on the part of its owner (or even by its occupant) may be voluntary, but any development that leads to the creation of impervious area leads to the involuntary subjection of the land to a stormwater user's fee. The only way the owner (or occupant) of the land can voluntarily "shut-off" the stormwater utility service is perhaps to return the land to its natural state. Finally, the impervious area component of stormwater management would necessarily apply to *all* developed land, including presently-developed land for which development decisions have already been made, many years ago. Generally, the extent to which property is developed is a function of the past and future decisions of the owner of the property.

Some of the literature dealing with stormwater utilities also distinguishes between stormwater "user" fees which are billed to utility customers in much the same manner as are other utility bills, and stormwater assessment fees, which are billed to property owners. There is no general law in Tennessee authorizing cities to impose special assessments for stormwater purposes, but some cities may have provisions in their charters generally authorizing them to levy special assessments on property. Those provisions in *some* cases may be sufficient authority for a particular city to impose the stormwater user's fee as a special assessment on property. Special assessments are generally not taxes. The question of whether a particular charter permits the stormwater user's fee to be levied as a special assessment should be determined on a case-by-cases basis.

Appendix D

Phase II Stormwater Communities in Tennessee

Appendix D - Phase II Storm Water Communities in Tennessee
Local Government MS4s Regulated by EPA Rule & Designated by Tennessee
September 9, 2002 (revised 12/2/2002)[1]

Introduction

This document identifies municipal separate storm sewer systems (MS4s) that will be regulated in Tennessee under the EPA Phase II storm water regulations. These are arranged below into groups according to the different categories each MS4 falls into, according to EPA regulations and specifics of Tennessee. There is a summary list at the end of this document.

"TDEC" refers the Tennessee Department of Environment and Conservation. "Division" refers to the Division of Water Pollution Control within the Department of Environment and Conservation.

A. Local governments listed in EPA rule

The following local governments were listed in appendix 6 of the EPA Phase II rule, promulgated in the federal register on December 8, 1999. All or part of the area within these jurisdictions was identified as urbanized area (UA) according to the 1990 US Census. The EPA rule mandates that all urbanized areas be regulated under the Phase II program.

Alcoa	Jackson	Anderson County
Bartlett	Johnson City	Blount County
Church Hill	Jonesborough	Carter County
Belle Meade	Kingsport	Hamilton County
Berry Hill	Lakesite	Hawkins County
Brentwood	Lakewood	Knox County
Bristol	Lookout Mountain	Loudon County
Clarksville	Maryville	Madison County
Collegedale	Mount Carmel	Montgomery County
East Ridge	Mount Juliet	Shelby County
Elizabethton	Oak Hill	Sullivan County
Farragut	Red Bank	Washington County
Forest Hills	Ridgeside	Williamson County
Germantown	Rockford	Wilson County
Goodlettsville	Signal Mountain	Sumner County
Hendersonville	Soddy-Daisy	

The above cities and counties must submit NPDES permit applications by March 10, 2003. The state intends to honor waiver requests for communities with an urbanized area population less than 1000.[2]

Counties in the above list are responsible to submit permit application material and implement complete Phase II programs only for those portions of the county that are urbanized, according to the Census Bureau's most recent definition and data.[3] The cities listed above are responsible to carry out Phase II programs in all of the city.

B. Cities and portions of counties that are located in urbanized areas (UAs) per the 2000 Census

Census 2000 enlarged most or all of Tennessee's 1990 urbanized areas. In addition, Cleveland, Morristown and Murfreesboro have been added as urbanized areas. As a result, TDEC's mapping indicates the following jurisdictions are partly or wholly urbanized. For this reason, they are, like the list in item A above, automatically subject to the Phase II program regulations and must apply for permit by March 10, 2003.

Urbanized area	Cities or portions of counties newly included in the urbanized area
Memphis, TN-MS-AK…….	Collierville, Millington

Nashville-Davidson……	Gallatin, Lavergne, Smyrna, Nolensville, Franklin, Ridgetop, Greenbrier, Springfield, Millersville, Robertson County
Chattanooga……	Walden
Knoxville……	Sevier County, Lenoir City
Bristol…….	Bluff City
Cleveland……	Bradley County
Morristown……..……	Hamblen County
Murfreesboro……..	Rutherford

Counties in the above list are responsible to submit permit application material and implement complete Phase II programs only for those portions of the county that are urbanized. The cities listed above are responsible to carry out the Phase II program in all of the city. The division intends to honor waiver requests for local government jurisdictions in which the urbanized area population is less than 1000 in the UA.

C. Non-UA cities meeting EPA examination criteria

According to the EPA rule, TDEC must evaluate whether or not storm water discharges from the following MS4s result in or have the potential to result in exceedances of water quality standards. These are cities that have a population of 10,000 or more and population density of 1000/square mile and are not in an urbanized area.

*Brownsville	Lawrenceburg	*Athens
*Cookeville	*McMinnville	*Columbia
*Dyersburg	*Shelbyville	*Dickson
(*Greeneville)	*Union City	*Lebanon
		*Martin

(Current population and city area of Greeneville indicate density is less than 1000/square mile.)

Our evaluation uses information from routine assessments of stream water quality – see the evaluation criteria in item E below – and selects those cities for which the division has made determination that urban runoff, storm sewers and/or land development is a source of pollutants or negative affects to streams in the area of the city. The ones marked with an asterisk show those cities for which such determination has been made.

Notes: The cities in the first and second columns are ones listed in the EPA rule of December 8, 1999, and reflect 1990 census data. EPA listed four other cities in the 1999 rule -- Collierville, Millington, Murfreesboro, and Springfield. These four cities are now urbanized areas per the 2000 census, as shown in item B above. The third column shows cities that, based on the 2000 census, have a population of 10,000 or more and density of 1000/square mile.

D. Additional non-UA cities with population over 10,000

1. Cities with population over 10,000

The division examined other cities of population over 10,000, but not a density of 10,000 people/square mile. Even though population density within city boundaries is less than 1000/square mile, the density in developed areas is above or near 1000/square mile. With each of these five cities, we have found that urban runoff, storm sewers and/or land development is a source of pollutants or negative affects to streams in the area of the city. These also will be designated as Phase II cities.

*Lewisburg *Oak Ridge *Sevierville *Tullahoma *Greeneville

2. High growth areas

TDEC is evaluating areas of the state that are showing high population growth, based on the second set of criteria given in part E below.

3. High tourist populations

The division believes that storm water quality management measures are presently needed in Sevier County, Gatlinburg and Pigeon Forge, because of population growth, land development, the high number of tourists and related services. We therefore propose regulating these areas as Phase II MS4s.

E. TDEC's evaluation criteria

TDEC is using two criteria to identify non-UA MS4s which discharge storm water that results in or has the potential to result in negative impacts to water quality.[4]

The first is whether or not urban runoff, storm sewers or land development from an MS4 is contributing to impaired water quality in nearby streams. The Division of Water Pollution Control makes such assessments routinely. Our lists of impaired streams, and causes and sources of pollutants, can be found in biennial reports titled "The Status of Water Quality in Tennessee" and in biennial 303(d) list reports.

The second set of criteria – as proposed - is based primarily on population growth.[5] If rapidly growing communities do not implement storm water management programs, the potential for negative impacts to nearby streams in the future is greater. The proposed growth criteria are the following:

- any urban cluster areas that have shown 40% or greater population growth over the previous ten years or 25% over the previous five years; or
- any urban cluster areas that have shown 25% or greater population growth over the previous ten years, or 15% for 5 years, and are adjacent to sensitive waters, are nearby (less than five miles) from an urbanized area, or are a significant contributor of pollutants to waters of the US.

F. The Designation Process

The Division will apply the first criteria above to cities of population 10,000 or greater, and the second set of criteria to urban areas (urban clusters) of population 10,000 or more. The urban cluster designations may include counties as well as cities. We will make designations by certified letter to the cities and counties in early December, 2002.[6] Designees will have 180 days from date of certified letter to submit permit applications. Our intent is that on a yearly basis, we will evaluate whether additional communities meet the designation criteria.

G. Procedure to Comment

The criteria and process above are being presented to EPA, to the regulated community and other interested parties for review and comment. We will receive comments until October 18, 2002. Submit comments to the following address:

Robert L. Haley, III
Tennessee Division of Water Pollution Control
L & C Annex, 6th Floor
401 Church Street
Nashville, Tennessee 37243-1534

Phase.two@state.tn.us

Summary list of regulated and designated small MS4s

Alcoa
Athens
Bartlett
Belle Meade
Berry Hill
Bluff City
Brentwood
Bristol
Brownsville
Church Hill
Clarksville
Cleveland
Collegedale
Collierville
Columbia
Cookeville
Dickson
Dyersburg
East Ridge
Elizabethton
Farragut
Forest Hills
Franklin
Gallatin
Gatlinburg
Germantown
Goodlettsville
Greenbrier
Greeneville
Hendersonville
Jackson
Johnson City
Jonesborough
Kingsport
Lavergne
Lakesite
Lakewood
Lebanon
Lenoir City
Lewisburg
Lookout Mountain
McMinnville
Martin
Maryville
Millersville
Millington
Mount Carmel
Mount Juliet
Morristown
Murfreesboro
Nolensville
Oak Hill
Oak Ridge
Pigeon Forge
Red Bank
Ridgeside
Ridgetop
Rockford
Sevierville
Shelbyville
Signal Mountain
Smyrna
Soddy-Daisy
Springfield
Tullahoma
Union City
Walden

Anderson County
Blount County
Bradley County
Carter County
Hamblen County
Hamilton County
Hawkins County
Knox County
Loudon County
Madison County
Montgomery County
Robertson County
Rutherford
Shelby County
Sullivan County
Washington County
Williamson County
Wilson County
Sevier County
Sumner County

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[1] This document was originally promulgated September 9, 2002. Subsequently, the division became aware that the Town of Walden is in the Chattanooga urbanized area, and Millersville is in the Nashville urbanized area, but these were not included in the list of regulated phase II communities. This revision dated 12/02/2002 is made to include Walden and Millersville.

[2] 40 CFR 122.32 (d). The NPDES permitting authority may waive permit coverage if your MS4 serves a population of less than 1,000 within the urbanized area and you meet the following criteria: (1) Your system is not contributing substantially to the pollutant loadings of a physically interconnected MS4 that is regulated by the NPDES storm water

program (see Sec. 123.35(b)(4) of this chapter); and (2) If you discharge any pollutant(s) that have been identified as a cause of impairment of any water body to which you discharge, storm water controls are not needed based on wasteload allocations that are part of an EPA approved or established ``total maximum daily load'' (TMDL) that addresses the pollutant(s) of concern.

[3] 40 CFR 122.32 (a). Part (a)(1) reads in part: "If your small MS4 is not located entirely within an urbanized area, only the portion that is within the urbanized area is regulated."

[4] 40 CFR 123.35 (b) includes the following language. In making designations of small MS4s, you [the NPDES permitting authority] must: (1)(i) Develop criteria to evaluate whether a storm water discharge results in or has the potential to result in exceedances of water quality standards, including impairment of designated uses, or other significant water quality impacts, including habitat and biological impacts.

[5] 40 CFR 123.35 (b)(1) continues as follows. (ii) Guidance: For determining other significant water quality impacts, EPA recommends a balanced consideration of the following designation criteria on a watershed or other local basis: discharge to sensitive waters, high growth or growth potential, high population density, contiguity to an urbanized area, significant contributor of pollutants to waters of the United States, and ineffective protection of water quality by other programs[.]

[6] 40 CFR 122.35 includes the following requirement. 122.35(b) "….In making designations of small MS4s, you must: …. (2) Apply such criteria, at a minimum, to any small MS4 located outside of an urbanized area serving a jurisdiction with a population density of at least 1,000 people per square mile and a population of at least 10,000[.]