STORM WATER
BEST MANAGEMENT PRACTICES
TECHNICAL MANUAL

CITY OF AUBURN

AUBURN

SYMBIONT

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Storm Water Best Management Practices Technical Manual
Auburn, Indiana

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ABBREVIATIONS

BMP	Best Management Practice
cfs	cubic feet per second
City	City of Auburn, Indiana
CWP	Center for Watershed Protection
FHWA	Federal Highway Administration
IDNR	Indiana Department of Natural Resources
IDEM	Indiana Department of Environmental Management
LID	Low Impact Development
MS4	Municipal Separate Storm Sewer System
NRCS	Natural Resource Conservation Service
SMRC	Storm Water Manager's Resource Center
SWCD	Soil and Water Conservation District
TR55	Urban Hydrology for Small Watersheds – Technical Report No. 55
USDOT	United States Department of Transportation
USEPA	United States Environmental Protection Agency

Section 1.0
INTRODUCTION

Uncontrolled runoff from construction sites is a water quality concern because of the devastating effects that sedimentation can have on local waterbodies, particularly small streams. Numerous studies have shown that the amount of sediment transported by storm water runoff from construction sites with no controls is significantly greater than from sites with controls. In addition to sediment, construction site activities yield pollutants such as solid and sanitary wastes, pesticides, petroleum products, construction chemicals, solvents, asphalts and acids that can contaminate storm water runoff. During storms, construction sites may be the source of sediment-laden runoff, which can overwhelm a small stream channel's capacity, resulting in stream bed scour, streambank erosion, and destruction of near-stream vegetative cover. Where left uncontrolled, sediment-laden runoff has been shown to cause physical, chemical and biological harm to the nation's receiving waters. Sedimentation also impacts municipal infrastructure by increasing the need for maintenance of conveyance systems required for proper operation of many storm water best management practices (BMPs).

There are generally two substantial impacts of post-construction runoff that include (1) an increase in the type and quantity of pollutants in storm water runoff, and (2) an increase in the quantity of water delivered to the waterbody. The pollutants often become suspended in runoff and are carried to receiving water where they can enter the food chain through small aquatic life, eventually entering the tissues of fish and humans. Increased impervious surfaces interrupt the natural cycle of gradual infiltration of water through vegetation and soil. The effects of this process include streambank scouring and downstream flooding, which often leads to a loss of aquatic life and damage to property.

In response to these threats, the City of Auburn is requiring construction activities to incorporate construction and post construction BMPs in planning documents to mitigate immediate and long term impacts to water resources during and after construction.

1.1 PURPOSE

This manual provides technical standards and guidance for proper design and installation of approved construction and post-construction BMPs in those areas where there is land disturbance greater than or equal to 1 acre, or disturbances of less than one acre of land that are part of a larger common plan of development or sale if the larger common plan will ultimately disturb one or more acres of land within the City of Auburn's municipal separate storm sewer system (MS4) area in accordance with the requirements of 327 IAC 15-13.

This manual serves as a companion to the City of Auburn's Construction Site Storm Water Runoff Control and Post Construction Storm Water Runoff ordinances, Chapters 161 and 162 of the Auburn Municipal Code, respectively, by providing specific information and design criteria on individual storm water BMPs that may be implemented to meet the ordinances requirements. In the case that this manual conflicts with the ordinances, the ordinances will prevail.

1.2 MANUAL ORGANIZATION

This manual is organized into eight sections in addition to appendices. Sections 1.0 and 2.0 provide an introduction to this technical manual and summarize the Federal and State storm water regulations for construction activities. Section 3.0 describes the storm water plan review procedures. Section 4.0 briefly discusses construction BMPs to be used during construction activities and directs the reader to the Indiana Department of Natural Resources (IDNR) document on construction site runoff. Sections 5.0 and 6.0 contain information in choosing and sizing post construction BMPs. Section 7.0 provides types and designs of Post Construction Structural BMPs. Sections 5.0, 6.0, and 7.0 are intended to be used in conjunction with the BMP fact sheets included in Appendix G. References are provided in Section 8.0.

Section 2.0
FEDERAL AND STATE STORM WATER REGULATIONS ON CONSTRUCTION ACTIVITIES

In response to the 1987 Amendments to the Clean Water Act (CWA), the United States Environmental Protection Agency (USEPA) developed Phase I of the NPDES Storm Water Program in 1990. The Phase I program addressed sources of storm water runoff that had the greatest potential to negatively impact water quality. Under Phase I, EPA required NPDES permit coverage for storm water discharges from medium and large municipal separate storm sewer systems (MS4s) located in incorporated places or counties with populations of 100,000 or more, and eleven categories of industrial activity which included construction activity that disturbed five or more acres of land.

The Phase II Storm Water Program, published in the Federal Register on December 8, 1999, required NPDES permit coverage for storm water discharges from certain regulated small MS4s; and construction activity disturbing between 1 and 5 acres of land (i.e., small construction activities).

The Indiana Administrative Code (IAC) regulates storm water discharge from various sources under general storm water rules, Rules 2, 3, 5, 6, and 13. The final versions of Rules 2, 3, 5, and 6 were adopted on May 8, 2003 and became effective on November 26, 2003. Rules 2 and 3 regulate general point source discharges associated with the Federal NPDES permit requirements. Rule 6 directly addresses storm water discharges exposed to industrial activities. Rule 5 regulates construction activities, and will be discussed in more detail in subsequent sections of this document. Rule 13 applies to operators of urban federal, state, municipal, county, public, or private separate storm water conveyance systems that are separated from the sanitary sewage conveyance. Rule 13 was adopted on March 12, 2003 and became effective on August 6, 2003. Rule 13 seeks to limit sediment discharge from construction activities by requiring MS4 operators to administer minimum control measures for construction and post construction activities within the operator's jurisdiction.

Section 3.0
STORM WATER PLAN REVIEW PROCEDURES

The City of Auburn has incorporated Storm Water Plan review procedures into their Construction Storm Water Run-off Control Ordinance Chapter 161. The purpose of these review procedures is to set consistent guidelines for the creation and review of storm water plans across the City of Auburn's MS4 Area. A copy of the ordinance is available in Appendix A. It is the contractor/developers responsibility to ensure that the version of ordinance available in this manual is the most current version approved by the City of Auburn.

Section 4.0
CONSTRUCTION BMPs

The Division of Soil Conservation of the Indiana Department of Natural Resources (IDNR) has published a comprehensive guide to erosion and sediment control practices to be used during construction (*Indiana Handbook for Erosion Control in Developing Areas* (October 1992)). A copy of this report is located in Appendix B. The handbook provides contractors, builders, developers, governmental officials, and others with guidelines and specific practices for controlling soil erosion and the nonpoint source pollution associated with the sediment in runoff. Adhering to these guidelines and properly applying the appropriate practices is required. The information below is summarized from this publication. Currently, the IDNR is in the process of the updating this handbook. Once the update is complete, the City of Auburn will revise this document as it deems necessary. The IDNR brochure: Erosion and Sediment Control for Individual Building Sites is included in Appendix C.

4.1 GENERAL PRINCIPLES

Section 2.1 of the *Indiana Handbook for Erosion Control in Developing Areas* lists ten general principles of erosion and sediment control. These principles are to be followed in the City of Auburn.

1) Fit the development to the existing terrain and soil.
2) Develop an erosion and sediment control plan before land-disturbing activities begin and follow it.
3) Retain existing vegetation on the construction site wherever possible.
4) Minimize the extent and duration that bare soil is exposed to erosion by wind and water.
5) Keep sediment on the construction site as much as possible.
6) If possible, divert off-site runoff away from disturbed areas.
7) Minimize the length and steepness of slopes.
8) Stabilize disturbed areas as soon as possible.
9) Keep velocity of runoff leaving the site low.
10) Inspect and maintain erosion control measures regularly.

4.2 SITE EROSION AND SEDIMENT CONTROL PRACTICE DESCRIPTIONS, STANDARDS, AND INSTALLATION SUMMARY

Section 3 of the *Indiana Handbook for Erosion Control in Developing Areas* describes numerous site specific and lot specific controls that can reduce erosion during construction activities. See Appendix B for specific purposes, requirements, installation procedures, maintenance procedures, and common concerns of specific BMPs within each of the nine categories of erosion controls listed below:

1) Site preparation
2) Surface stabilization
3) Runoff control
4) Runoff conveyance
5) Outlet protections
6) Temporary drop inlet protections
7) Temporary curb inlet protections
8) Sediment traps and barriers
9) Other related practices

Construction BMPs could also be divided into two groups based on their general control mechanisms: erosion control and sediment control. Erosion control BMPs reduce the volume of sediment generated onsite and therefore reduce the treatment volume and clean out frequencies of sediment control BMPs. Many erosion control BMPs also reduce water velocity and volume, in turn protecting perimeter controls. Sediment control BMPs trap eroded sediment, generally onsite, to prevent it from reaching waterways. An effective construction site pollution prevention plan and an implementable post construction BMP operation and maintenance plan will mitigate sedimentation impacts in the storm sewer conveyance and ultimately in the receiving streams.

Section 5.0
POST CONSTRUCTION BMP SIZING CRITERIA

Post construction BMPs can be divided into two groups: structural and nonstructural BMPs. Structural BMPs are generally designed to remove constituents in storm water runoff, whereas nonstructural measures focus on the prevention of source-related constituent-generating activities from contaminating storm water (e.g., covering salt piles) and on the removal of constituents that might contaminate storm water (e.g., streetsweeping). Structural BMPs are discussed in this technical manual. Nonstructural BMPs are primarily the responsibility of a municipality and therefore are not discussed in this report.

The City of Auburn has chosen to size BMPs within their MS4 Area for water quality protection based on current regulatory requirements and the City's desire to improve the water quality of their local watercourses. The DeKalb County Surveyor's Office proposed criteria do not allow more than 0.2 cubic feet per second (cfs)/acre to be discharged from a development and as such BMPs will be sized for both water quality and quantity. BMPs need to be built to handle the larger of the two volumes determined in the following sections.

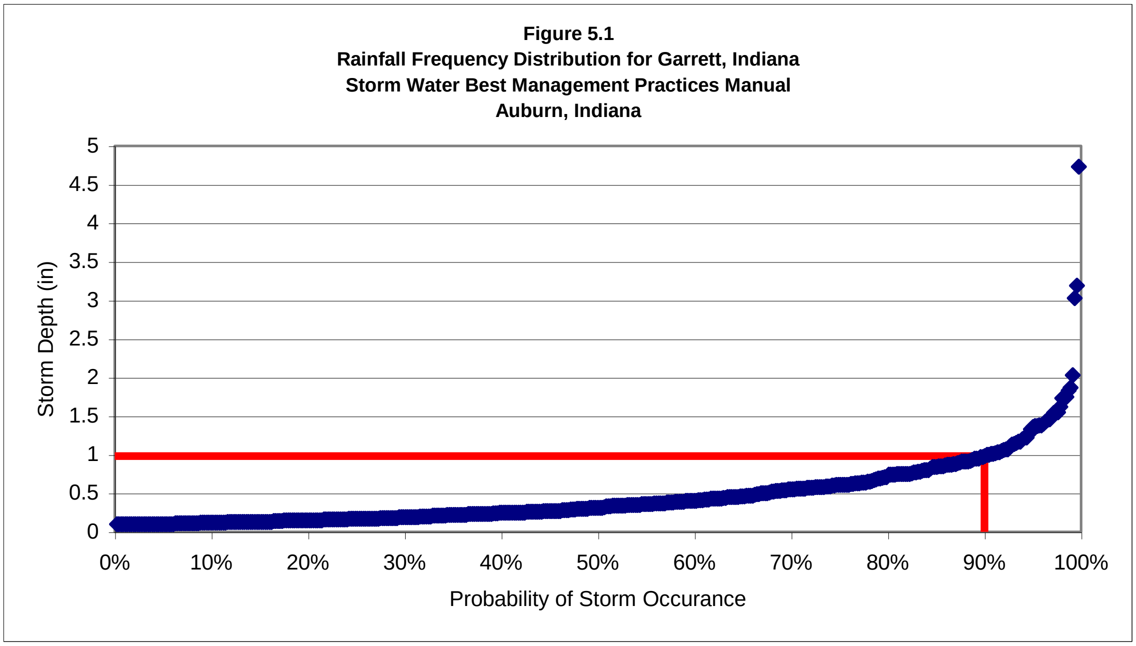
5.1 SIZING FOR WATER QUALITY (WQ_v)

It is widely recognized that in order to meet various in-stream water quality monitoring standards and classifications, it is necessary to provide some level of storm water quality treatment. Sizing post construction BMPs for water quality is indirectly accomplished by sizing BMPs to capture and treat a specific volume of water and constructing the BMP in accordance with manufacturer's recommendations or municipal guidelines. By sizing for volume, the BMP will capture the majority of the pollutants moving off the land surface. The goal of water quality sizing criteria is to improve storm water quality, while maintaining a reasonable cost for BMP implementation. The sizing for BMPs is calculated using the 90% rainfall occurrence frequency and total impervious surface of the development. Once the final size is determined, proceed to Section 6.0 to choose which BMP (or series of BMPs) would be most applicable in your particular construction project.

This section will present basic options for storm water quality control, provide default criteria, and discuss tools of analysis to evaluate site pollutant loads.

Sizing for 90% Rainfall Event

BMPs are sized so that the BMP will capture and treat approximately 90% of the average annual storm water runoff volume (WQ_v). The specific rainfall event captured is the 90% storm event, or the storm event that is greater than or equal to 90% of all 24-hour storms on an annual basis. This value is determined by investigating local rainfall records to develop a rainfall frequency spectrum. The rainfall frequency spectrum represents the statistical distribution of 24-hour rainfall events. Please note that the 90% rainfall event is not calculated based on the annual volume, but rather as a percentile of individual events. As the NOAA weather station in Auburn, Indiana was decommissioned in the late 90's, weather data from 2000-2005 from Garrett, Indiana was used to determine the 90% rainfall frequency event (Figure 5.1).



The WQ_v (in acre-feet) shall be equal to:

$$WQ_v = (0.98) \times (0.05+0.9I) \times (A)/12$$

Where:

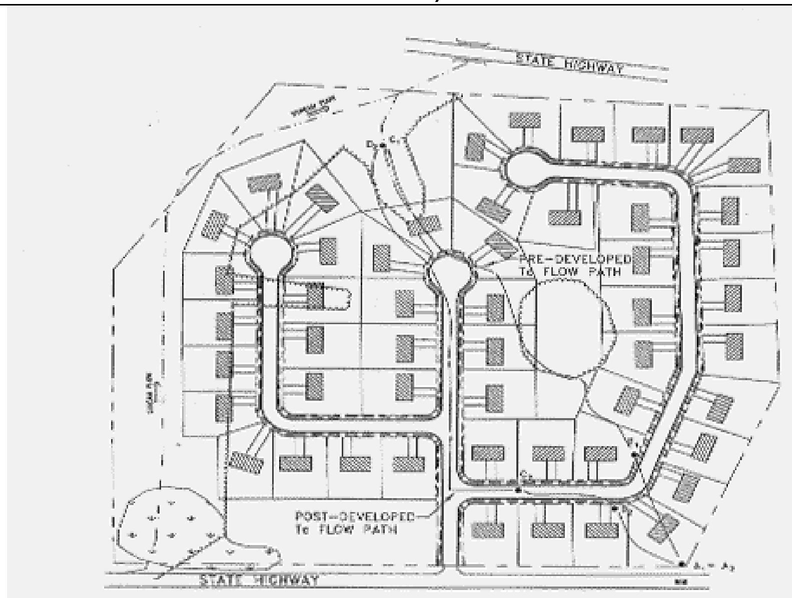
0.98	=	90% Rainfall event in Auburn, IN
A	=	Site Area (acres)
I	=	Site Impervious Cover (decimal)

BMP Sizing Examples

Design Example 1: Residential Development – Swann Center

This section presents a sizing example for a medium residential subdivision, Swann Center if it were being built in Auburn, Indiana. The layout of the Swann Center subdivision is shown in Figure 5.2.

Figure 5.2
Swann Center
Storm Water Best Management Practices Technical Manual
Auburn, IN



Base Data

Location: Auburn, IN
Site Drainage Area = **38.0** acres
Measured Impervious Area = 13.8 acres;
I=13.8/38 = **0.363**

Source: Adapted from CWP, 2000.

Compute Water Quality Volume WQ_v

$$WQ_v=(0.98)\ (0.05+0.9I)\ (A/12)$$

Where:

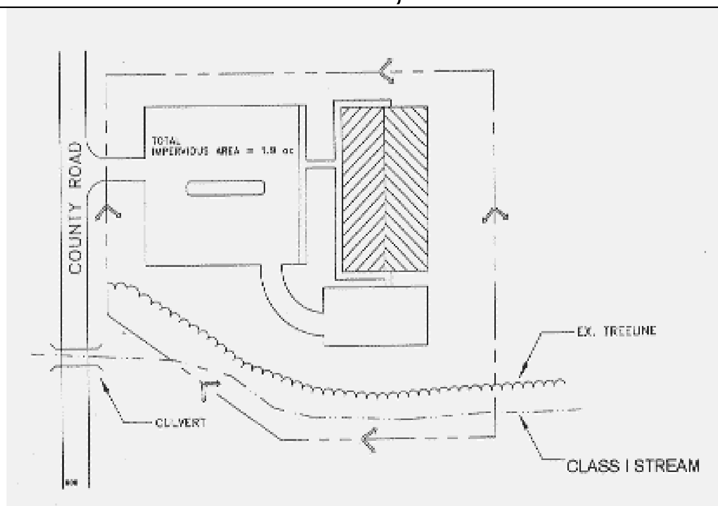
I = 0.363
A = 38.0 acres

WQ_v = (0.98) (0.05 + 0.9 x 0.363) (38.0) (1/12) = 1.17 acre-feet

Design Example No. 2: Commercial Development – Brown Community Center

This is a sizing example for a commercial site, Brown Community Center. The layout of the Brown Community Center is shown in Figure 5.3.

Figure 5.3
Brown Community Center
Storm Water Best Management Practices Technical Manual
Auburn, IN



<u>Base Data</u>

Location: Auburn, IN
Site Drainage Area = **3.0** acres
Impervious Area = 1.9 acres;
I=1.9/3.0 = **.633**

Source: Adapted from CWP, 2000.

<u>Compute Water Quality Volume WQ_v</u>

WQ_v = (.98) (0.05+0.9I) (A/12)

Where:

- I = 0.633
- A = 3.0 acres

WQ_v = (0.98) (0.05 + 0.9 x 0.633) (3.0) (1/12) = <u>0.15 acre-feet</u>

5.2 SIZING FOR WATER QUANTITY (FLOOD CONTROL)

The primary purpose of water quantity (flood control) sizing criteria is to reduce peak discharge from storm events to reduce the impact of local and "catastrophic" flood events. The City of Auburn has determined that all storm water management activities will also need to follow guidelines set forth by the DeKalb County Surveyor's office. The County Surveyor is responsible for regulating all county drains (ditches), including those within the City of Auburn. The sizing criteria for water quantity recommended by the DeKalb County Surveyor is that in a one hundred year storm, development and re-development projects that discharge storm water into an open drain will be allowed a 0.2 cfs per acre discharge. Projects that tie into tile drains in good condition will be allowed a discharge of between 0.02 and 0.05 cfs/acre. The owner will need to contact the DeKalb County Surveyor to confirm what discharge limit is applicable. BMPs need to be sized to provide the appropriate reduction in peak flow from the pre-developed to the post-developed conditions.

The City of Auburn has determined that calculations for predevelopment peak flows and volumes to be used to size BMPs to achieve the rate reduction detailed above be done using the procedures in Urban Hydrology for Small Watersheds TR No. 55 published by NRCS. Example worksheets from this document are included in Appendix D.

Other methods for estimating peak flow and runoff volume need to be approved by the City of Auburn prior to use.

5.3 FINAL BMP VOLUME

The owner shall use the larger of the two volumes determined in the previous sections for designing the post construction BMPs.

5.4 SPECIAL SIZING CONSIDERATIONS FOR HYDROCARBONS

The City of Auburn encourages the maximum removal of hydrocarbons possible for all developments encompassing more than 5 acres of impervious area. The BMPs available to meet the water quality or any water quantity storage requirements should be evaluated for their hydrocarbon removal and the BMPs with the highest possible hydrocarbon removal should be chosen and implemented. The City of Auburn Post Construction Runoff Control Ordinance should be reviewed for any specific requirements.

Section 6.0
POST CONSTRUCTION STRUCTURAL BMP SELECTION PROCESS

6.1 STRUCTURAL BMP DESCRIPTION

Structural BMPs can be divided into six categories based on the mechanistic characteristics of storm water treatment such as storage, flow attenuation, infiltration, filtration, and biological degradation.

1. Detention/Retention Systems
2. Infiltration Systems
3. Filtering Systems
4. Vegetated Swales/Filter Strips
5. Water Quality Inlets
6. Low Impact Development

Detention/Retention Systems primarily include detention ponds, retention ponds, and wetlands. These treatment practices are designed to store water allowing solids and associated pollutants to settle before gradually releasing the water to the receiving stream or storm sewer system. Detention ponds or basins do not have a permanent pool of water between runoff events. Underground tanks can also be used for storm water detention. Retention ponds or basins are designed to capture a volume of runoff and retain that volume until it is displaced by the next runoff event. Retention systems are often better for water quality control than detention ponds. Constructed Wetland systems are included as part of retention systems. Porous pavements could be included in this category if the runoff that passes through the pavement is being stored underground.

Infiltration Systems include infiltration basins, infiltration trenches, and bioretention. Infiltration technologies are designed to capture a volume of storm water runoff, retain it, and infiltrate that volume into the ground. Water quality is improved as solids are captured within the soil. Infiltration systems are underground and as such are well suited to underground environments but care needs to be taken to ensure the correct soil types and groundwater table characteristics are present. Porous pavements could be included in this category if the runoff that passes through the pavement is being infiltrated into the ground.

Filtering Systems include underground sand filters, surface sand filters, and organic media filters. A filtering system uses a media such as sand, gravel, peat, or compost to remove a portion of constituents found in storm water. Filters have a variety of styles to meet various site constraints and are sized to provide treatment for the water quality volume. Bioretention is infiltration through organic matter with vegetation growing in it that enhances constituent removal.

Vegetated Swales/Filter Strips include vegetated swales, grass swales, and filter strips. These BMPs are designed to capture and filter runoff with a portion infiltrating into the soil and are often used while conveying the runoff in an open channel. These BMPs are most often used alongside roadways or preceding other BMPs to pretreat the storm water. Swales can be designed to be wet or dry, depending on site conditions. Level spreaders are commonly used to spread runoff out into sheet flow before passing over filter strips.

Water Quality Inlets include most manufactured systems such as catch basin inserts, oil/grit or oil/water separators, vortex separators, etc. These BMPs often use combinations of detention, retention, and filtering to improve water quality and/or reduce peak flows. Many vendor-supplied systems work well for storm water control and can be fit to varying site conditions. Pollutant removal percentages need to be independently verified before being submitted for a site.

Low Impact Development (LID) practices are those practices that control storm water where it is generated. LID practices include porous pavement, rain barrels, green roofs, rain gardens, and tree box filters and are meant to be distributed throughout a site to minimize runoff. Removal percentages for many LID practices are difficult to quantify as they prevent the runoff from occurring instead of merely treating it. LID practices can reduce the runoff to more conventional BMPs.

BMP SELECTION

In this section, a three-step decision-making process employing both quantitative and qualitative criteria for sequentially screening structural BMPs as described in *Storm Water Best Management Practices in an Urban Setting: Selection and Monitoring* (FHWA) using supporting data from that publication as well as from the Storm water Managers Resource Center (SMRC). A preferred management plan (a single BMP or a combination of BMPs) suited to site-specific conditions is the result of this process. This process builds on the knowledge and information summarized in the *Storm Water Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring* (FHWA).

The proposed BMP selection process is designed as a sequential approach that incorporates a series of checks and balances at each stage, integrates management objectives and site conditions, and relies on current knowledge of storm water BMP technology and demonstrated experience and case studies. The process is designed to allow decisions to progress from a preliminary screening level to a more detailed evaluation and selection of candidate best management alternatives. The three steps of this selection process include: a scoping phase, an evaluation phase, and a final selection phase.

To ensure a successful BMP selection process, several supporting data collection activities are critical. Data include:

1. Available information on BMPs and their use
2. Drainage area characteristics and qualitative evaluation of the sources and magnitude of constituents
3. Physical constraints of the site
4. Local cost estimates including land acquisition, construction and maintenance cost
5. Public acceptance and any additional benefits provided (e.g. aesthetics, recreational value).

Step 1 – The Scoping Phase

The scoping phase provides an initial screening analysis of potential structural BMPs approved by the City of Auburn for use in construction and post construction activities within its jurisdiction. The key process in this phase is to sequentially eliminate nonapplicable BMPs based on a predefined set of criteria. The scoping phase may address the following questions:

- Will the proposed landuse limit the implementation of an individual BMP?
- Does the BMP address one or more management objectives?
- Does the BMP provide both storm water quantity and quality control?
- Is the BMP costly to implement?
- Does the BMP provide auxiliary benefits such as public education?

Planned landuse, management goals and objectives, and cost are used to evaluate BMPs in the scoping phase.

<u>Planned Land Use</u>

The proposed land Use of the construction project will have great implications as to which BMPs will be most appropriate for implementation at a site. Table 6.1 summarizes the applicability and feasibility of implementing BMPs for six common land Uses:

- *Rural*. Identifies BMPs that are best suited to treat runoff in rural or very low density areas.

- *Residential*. Identifies BMPs in medium to high density residential developments.

- *Roads and Highways*. Identifies appropriate BMPs to treat runoff from major roadways and highway systems.

- *Commercial Development*. Identifies practices that are suitable for new commercial development

- *Hotspot Land Uses*. Examines the capability of a BMP to treat runoff from designated hotspots. A BMP that receives hotspot runoff may have design restrictions, as noted.

- *Urban Sites*. Identifies BMPs that work well in the urban environment, where space is limited and original soils have been disturbed. These BMPs are frequently used at redevelopment sites.

Table 6.1
Feasibility of BMP Implementation in Different Land Uses
Storm Water Best Management Practices Technical Manual
Auburn, Indiana

BMP Group	BMP Design	Rural	Residential	Roads and Highways	Commercial/ High Density	Hotspots	Urban
Detention / Retention Systems	Detention Pond	Y	Y	Y	Y	1	N
	Detention Tank	Y	Y	N	Y	1	N
	Retention Pond	Y	Y	Y	Y	1	N
	Wetland	Y	Y	Y	Y	1	N
Infiltration Systems	Infiltration Trench	D	D	Y	Y	N	D
	Infiltration Basin	D	D	D	D	N	D
Filtering Systems	Underground Sand Filter	N	N	D	Y	2	Y
	Surface Sand Filter	N	D	Y	Y	2	Y
	Organic Media Filter	N	D	Y	Y	2	Y
	Bioretention	D	D	Y	Y	2	Y
Vegetated Swales and Filter Strips	Vegetated Swale	Y	D	Y	D	2	D
	Vegetated Filter Strips	Y	D	D	D	2	D
	Level Spreader	Y	D	D	D	D	D
Water Quality Inlets	Catch Basin Inlets	N	Y	N	Y	Y	Y
	Oil-Grit Separators	N	Y	N	Y	Y	Y
	Other Manufactured Systems	N	N	D	D	D	D
Low Impact Development	Porous Pavement	N	Y	Y	Y	2	Y
	Green Roofs	N	N	N	Y	D	D
	Rain Gardens	D	Y	D	D	2	Y
	Rain Barrels / Cisterns	D	D	N	N	N	D
	Tree Box Filters	N	Y	Y	D	D	D

Y = Yes. Good option in most cases
D = Depends. Suitable under certain conditions, or may be used to treat a portion of the site.
N = No. Seldom or never suitable.
1 = Acceptable option, but may require a pond liner to reduce risk of groundwater contamination
2 = Acceptable option, if not designed as an exfilter.
Source: Adapted from CWP, 2000, FHWA, 2000.

Management Goals and Objectives

A post construction storm water management program should focus on meeting well-defined environmental protection goals and public needs in a cost-effective manner. In many cases, a post construction storm water management plan is designed to address multiple environmental and safety concerns at various scales ranging from site-specific to a larger watershed scale. The development and implementation of storm water management plans are driven by a variety of conditions including public pressure, applicable regulations and policies, downstream impacts on sensitive resources, or a combination of any of these conditions. Within these plans, downstream impacts are usually expressed qualitatively in terms of objective statements such as "control of flooding conditions", or "restoration of a water quality impairment."

Meeting these multiple objectives may require that several potential BMP locations be identified and considered. Potential BMPs can be determined for each site location to form a comprehensive management action plan. These selected BMPs, as well as the overall management actions (whether at the site-specific drainage area or at the watershed scale), will contribute to achieving the predefined management objective(s). An in-depth understanding of storm water management objectives prior to the selection of a BMP or combination of BMPs is essential to the development of a successful management plan. This understanding should facilitate the development of management objectives into measurable indicators or criteria that can be used to screen out nonapplicable BMPs.

The objectives provided here will be used to help illustrate which of these objectives may be achieved by the BMPs analyzed during the selection process. Table 6.2 lists the applicable objectives to construction activities in the City of Auburn. The urban setting column identifies BMPs with relatively small footprints, design adaptability, and effectiveness in removing typical constituents from storm water.

Table 6.2
Primary Function of BMPs and Ability to Address Management Objectives
Storm Water Best Management Practices Technical Manual
Auburn, Indiana

BMP Group	BMP Types	Ultra Urban Compatible	Flood Control	Water Quality Constituent Removal Effectiveness	
				Suspended[1]	Dissolved[1]
Detention / Retention Systems	Detention Pond	No	Yes	High	Moderate
	Detention Tank	Yes	Yes	High	Moderate
	Retention Pond	No	Yes	Moderate	High
	Wetland	No	No	High	High
Infiltration Systems	Infiltration Trench	Yes	No	High	Moderate
	Infiltration Basin	No	Yes	High	Moderate
Filtering Systems	Underground Sand Filter	Yes	No	High	Low
	Surface Sand Filter	No	No	Moderate	High
	Organic Media Filter	Yes	No	High	High
	Bioretention	Yes	No	High	Moderate
Vegetated Swales and Filter Strips	Vegetated Swale	Yes	No	Moderate	Moderate
	Vegetated Filter Strips	No	No	Low	Low
	Level Spreader	Yes	No	Low	Low
Water Quality Inlets	Catch Basin Inlets	Yes	No	Low	Low
	Oil-Grit Separators	Yes	No	Low	Low
	Other Manufactured Systems	Yes	No	Low	Low
Low Impact Development	Porous Pavement	Yes	Yes	Low	Moderate
	Green Roofs	Yes	Yes	Moderate	Moderate
	Rain Gardens	Yes	Yes	Moderate	Moderate
	Rain Barrels / Cisterns	Yes	No	High	Moderate
	Tree Box Filters	Yes	No	Moderate	Moderate

[1]Note: Suspended constituents include suspended solids as well as oil/grease, metals, nutrients, and trace organics associated with suspended solids. Dissolved constituents include soluble trace metals, nutrients, and trace organics.

Source: As adapted from FHWA, 2000, *Storm Water Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring*, Office of Natural Environment, USDOT, Washington, DC. and other sources

Other Management Objectives

Initial screening of the suite of available BMPs can also be performed based on elements that are not related to the performance of the BMP. For example, fiscal management objectives such as providing storm water management for a specified dollar amount or a percentage of the total project cost can serve as a means to remove high-cost BMPs from further consideration. Table 6.3 indicates the relative cost for various BMPs. A final comparative analysis of costs for recommended BMP alternatives is completed in the final selection phase.

Table 6.3
Relative Rankings of Cost Elements and Effective Life of Structural BMP Options
Storm Water Best Management Practices Technical Manual
Auburn, Indiana

BMP Group	BMP Types	Capital Costs	O&M Costs	Effective Life[1]
Detention / Retention Systems	Detention Pond	Moderate	Low	20 – 50 years
	Detention Tank	Moderate to High	High	50 – 100 years
	Retention Pond	Moderate	Low	20 – 50 years
	Wetland	Moderate to High	Moderate	20 – 50 years
Infiltration Systems	Infiltration Trench	Moderate to High	Moderate	10 - 15 years
	Infiltration Basin	Moderate	Moderate	10 – 15 years
Filtering Systems	Underground Sand Filter	High	High	5 - 20 years
	Surface Sand Filter	Moderate	Moderate	5 - 20 years
	Organic Media Filter	High	High	5 - 20 years
	Bioretention	Moderate	Low	5 - 20 years
Vegetated Swales and Filter Strips	Vegetated Swale	Low to Moderate	Low	5 - 20 years
	Vegetated Filter Strips	Low	Low	20 - 50 years
	Level Spreader	Low	Low	5-20 years
Water Quality Inlets	Catch Basin Inlets	Low	Moderate to High	10 - 20 years
	Oil-Grit Separators	Moderate	High	50 - 100 years
	Other Manufactured Systems	Moderate	Moderate	50 - 100 years
Low Impact Development	Porous Pavement	Low	Moderate	15 - 20 years
	Green Roofs	Moderate	Low to Moderate	30 – 40 Years
	Rain Gardens	Low	Low	5 – 20 years
	Rain Barrels / Cisterns	Low	Low	10 – 20 years
	Tree Box Filters	Low	Low	5 – 20 years

[1] Assumes regular maintenance, occasional removal of accumulated materials, and removal of any clogged media.
Source: FHWA, 2000 and other sources

Step 2 – Evaluation of Structural BMPs

The evaluation phase provides a more detailed process to evaluate the ability of structural and nonstructural BMPs to meet management objectives. The evaluation phase consists of three types of analysis. First, the list of potential structural BMPs is further narrowed down using criteria derived from the physical characteristics of the site. Second, BMP effectiveness information is used to identify and rank BMPs with demonstrated performance in controlling targeted constituents. Finally, combinations of the remaining BMPs should be evaluated for their compatibility and complimentary performance with nonstructural BMPs. This process results in a final list of BMP options that can be ranked to optimize selection. Questions to consider are:

- Is the BMP applicable to site conditions?
- Are data available on BMP effectiveness?
- Could the addition of nonstructural BMPs improve the performance or maintenance requirements of a structural BMP?

Characteristics of the site

Site characterization includes evaluation of the drainage area to identify runoff and constituent-generating activities and sources, and characterization of the magnitude and the extent of each source. Characterization of dominant sources and constituents, definition of the constituent fate and transport pathways, and identification of the method and processes by which constituents enter storm water runoff are key elements supporting the selection of appropriate urban BMPs. Table 6.4 lists site considerations for structural BMP use.

Table 6.4a
Site Considerations for Structural BMPs
Storm Water Best Management Practices Technical Manual
Auburn, Indiana

BMP Group	BMP	Area Typically Served (acre)	Area Required for BMP[1]	Site Slope	Minimum Head Requirement (ft) [2]
Detention / Retention Systems	Detention Pond	2 min	10-20%	<15%	3 - 6
	Detention Tank [3]	1 – 2	0.5-1%	NA	5 - 8
	Retention Pond	2 min	20-25%	<15%	3 - 6
	Wetland	1 min	10%	<8%	1 - 8
Infiltration Systems	Infiltration Trench	2 – 4	2-4%	<6%	3 – 8
	Infiltration Basin	2 – 20	2-4%	<10%	2 – 4
Filtering Systems	Underground Sand Filter	2 – 5	2-3%	<6%	1 – 8
	Surface Sand Filter	2 – 5	2-3%	<6%	5 – 8
	Organic Media Filter	2 – 5	2-3%	<6%	5 – 8
	Bioretention	1 – 50	4-10%	<6%	2 – 4
Vegetated Swales and Filter Strips	Vegetated Swale	2 – 4	10-20%	<4%	2 – 6
	Vegetated Filter Strips	NA	25%[4]	<4%	Negligible
	Level Spreader	Function of flow not area	1-2%	NA	1 –2
Water Quality Inlets	Catch Basin Inlets	< 1	None	NA	1 – 2
	Oil-Grit Separators	1 – 2	< 1%	NA	3 – 6
	Other Manufactured Systems	1 – 10	None	NA	4
Low Impact Development	Porous Pavement	2 – 4	NA	>1%	NA
	Green Roofs	<1	NA	NA	NA
	Rain Gardens	<1	25%	<12%	1 – 4
	Rain Barrels / Cisterns	<0.1	<1%	NA	1 – 10
	Tree Box Filters	0.5	<1%	<15%	1 – 4

NA = Not Applicable or Not Available

1. Expressed as a percent of the total drainage area, can be modified to accommodate ultra-urban conditions.
2. Either the depth of water in the typical design or the total drop in water level for flow-through designs.
3. Based on storage of 0.5 in of runoff per acre of imperviousness.
4. Minimum recommended for best treatment efficiency.

Source: FHWA and CWP, 2000

Table 6.4b
Site Considerations for Structural BMPs
Storm Water Best Management Practices Technical Manual
Auburn, Indiana

BMP Group	BMP	In Situ Soils [1]	Climate a Significant Factor? [2]	Water Table
Detention / Retention Systems	Detention Pond	Independent	No	2ft if hotspot or aquifer
	Detention Tank	Independent	No	NA
	Retention Pond	Independent	Yes	2ft if hotspot or aquifer
	Wetland	Dependent	Yes	2ft if hotspot or aquifer
Infiltration Systems	Infiltration Trench	Percolation > 0.5 in/hr	Yes	4ft
	Infiltration Basin	Percolation > 0.5 in/hr	Yes	4ft
Filtering Systems	Underground Sand Filter	Independent	No	2ft
	Surface Sand Filter	Independent	Yes	2ft
	Organic Media Filter	Independent	Yes	2ft
	Bioretention	Independent[3]	Yes	2ft
Vegetated Swales and Filter Strips	Vegetated Swale	Dependent	Yes	2ft
	Vegetated Filter Strips	Dependent	Yes	2ft
	Level Spreader	Dependent	No	4ft
Water Quality Inlets	Catch Basin Inlets	Independent	No	NA
	Oil-Grit Separators	Independent	No	NA
	Other Manufactured Systems	Independent	No	Varies
Low Impact Development	Porous Pavement	Dependent	NA	NA
	Green Roofs	Independent	Yes	NA
	Rain Gardens	Dependent	Yes	4ft
	Rain Barrels / Cisterns	Independent	No	NA
	Tree Box Filters	Dependent	Yes	4ft

NA = Not Applicable or Not Available

1. Relevancy of soil types to the design of the BMP
2. Climate issues to consider include prolonged drought and freeze periods.
3. When equipped with an under drain system.

Source: FHWA and CWP, 2000

BMP Effectiveness

The City of Auburn requires that 80% of the post construction TSS be removed prior to discharge into the MS4 conveyance system. BMPs can be chosen that meet this requirement by themselves or in combination with other BMPs. The responsibility for ensuring a BMP is performing to the effectiveness needed lies with the owner of the BMP not the City.

The screening of structural BMPs is intended to eliminate those BMPs that are obviously impractical, implausible, or ineffective. It is unlikely that any single BMP will be able to completely meet all management objectives; tradeoffs between cost and performance almost always occur. Often, more than one BMP will be necessary. The resources and effort required to evaluate these tradeoffs make it desirable to remove from consideration any BMPs that do not fulfill or do not contribute significantly in combination with other BMPs to fulfilling management objectives. The nature and scope of the planned project, water quantity and quality management objectives, and any other limiting management objectives should be used to evaluate the suite of available structural BMPs. BMP pollutant removal efficiency is noted in Table 6.5.

Table 6.5a
Pollutant Removal Effectiveness (%)
Storm Water Best Management Practices Technical Manual
Auburn, Indiana

BMP Group	BMP	TSS	TP	TN	NO_3
Detention / Retention Systems	Detention Ponds	61	19	31	NA
	Detention Tanks	60-80	20-40	NA	NA
	Wet Retention Pond	67	48	31	24 - 60
	Wetlands	65	25	20	NA
Infiltration Systems	Infiltration Trench[1]	75 - 99	50 - 75	45 - 70	NA
	Infiltration Basin[1]	75 - 99	50 - 70	45 - 70	NA
Filtering Systems	Underground Sand Filters	70 - 90	43 - 70	30 - 50	NA
	Surface Sand Filters	75 - 92	27 - 80	27 - 71	0 - 23
	Organic Media Filters	90 - 95	49	55	NA
	Bioretention[1]	75	50	50	NA
Vegetated Swales and Filter Strips	Vegetated Swales	30 - 90	20 - 85	0 - 50	NA
	Vegetated Filter Strips	27 - 70	20 - 40	20 - 40	NA
	Level Spreader	<25	<25	<25	<25
Water Quality Inlets	Catch Basin Inserts	Varies based on product chosen			
	Oil-Grit Separators	20 - 40	< 10	< 10	NA
	Manufactured Systems	Varies based on product chosen			
Low Impact Development	Porous Pavement	82 - 95	60 - 71	80 - 85	NA
	Green Roofs	90	100	20	NA
	Rain Gardens [1]	75	50	50	NA
	Rain Barrels / Cisterns	Varies based on what happens to stored water			
	Tree Box Filters	85	74	68	NA

NA = Not Applicable or Not Available.
TSS = Total Suspended Solids
TP = Total Phosphorus
TN = Total Nitrogen
NO_3 = Nitrates
Removal efficiencies may be based on either mass balance or average concentration calculations. The values may originate from evaluation of multiple events or from long-term monitoring. Ranges are provided wherever possible.
[1] Based on capture of 0.5 in of runoff volume. Effectiveness directly related to volume of captured runoff.
Source: As adapted from FHWA, 2000, *Storm Water Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring*, Office of Natural Environment, USDOT, Washington, DC.

Table 6.5b
Pollutant Removal Effectiveness (%)
Storm Water Best Management Practices Technical Manual
Auburn, Indiana

BMP Group	BMP	Metals	Bacteria	Oil & Grease	TPH
Detention / Retention Systems	Detention Ponds	26-54	NA	NA	NA
	Detention Tanks	NA	NA	NA	NA
	Wet Retention Pond	25	65	NA	NA
	Wetlands	35 - 65	NA	NA	NA
Infiltration Systems	Infiltration Trench[1]	75 - 99	75 - 98	NA	75
	Infiltration Basin[1]	50 - 90	75 - 98	NA	75
Filtering Systems	Underground Sand Filters	22 - 91	NA	NA	NA
	Surface Sand Filters	33 - 91	NA	NA	NA
	Organic Media Filters	48 - 90	90	90	90
	Bioretention[1]	75 - 80	NA	NA	75
Vegetated Swales and Filter Strips	Vegetated Swales	0 - 90	NA	75	NA
	Vegetated Filter Strips	40-50	NA	NA	NA
	Level Spreader	<25	<25	<25	<25
Water Quality Inlets	Catch Basin Inserts	Varies based on product chosen			
	Oil-Grit Separators	< 10	NA	50 - 80	NA
	Manufactured Systems	Varies based on product chosen			
Low Impact Development	Porous Pavement	33 - 99	NA	NA	NA
	Green Roofs	80	65	NA	NA
	Rain Gardens [1]	75 - 80	NA	NA	75
	Rain Barrels / Cisterns	Varies based on what happens to stored water			
	Tree Box Filters	82	NA	NA	NA

NA = Not Applicable or Not Available.
TPH = Total Petroleum Hydrocarbons
Removal efficiencies may be based on either mass balance or average concentration calculations. The values may originate from evaluation of multiple events or from long-term monitoring. Ranges are provided wherever possible.
[1] Based on capture of 0.5 in of runoff volume. Effectiveness directly related to volume of captured runoff.
Source: As adapted from FHWA, 2000, *Storm Water Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring*, Office of Natural Environment, USDOT, Washington, DC.

Nonstructural Compatibility and Complimentary Performance

The ability of a nonstructural BMP to remove specific constituents prior to contamination of storm water makes them ideal for combining with and enhancing the effectiveness of structural BMPs. Nonstructural and structural BMPs can be used together and structural BMPs can be combined in an urban environment to optimize pollution control. Once the structural BMP selection process has produced a narrowed set of options, the feasibility of their combination with selected nonstructural BMPs can be evaluated. The result of this analysis might be a BMP or group of BMPs specifically grouped to address the urban area in question. Nonstructural BMPs can enhance the performance of structural BMPs by preventing the entry of constituents that are difficult for structural BMPs to remove, and/or reducing the structural BMP maintenance requirements.

A listing of nonstructural BMPs as given by FHWA is included in Table 6.6 below.

Table 6.6
Nonstructural BMP Types by Category
Storm Water Best Management Practices Technical Manual
Auburn, Indiana

BMP	
Litter and Debris Removal	**Landscaping and Vegetation Practices**
Property maintenance	Landscaping/Groundskeeping programs
Proper dumpster placement	**Litter and Debris Control**
Stream Clean-ups	Road maintenance
Frequent storm drain maintenance	Street Sweeping
Parking lot sweeping	Adopt-A-Road program
Education and Training	Adopt-A-Stream program
Storm drain stenciling	**Pesticide and Fertilizer Application**
Employee education	Pesticide application control
Containment and Diversion	**Landscaping and Vegetation Practices**
Covered fueling stations	Mowing reduction
Covered raw material storage	**Chemical Handling and Storage**
Elimination of non-storm water discharges and connections	Proper hazardous materials use and storage
Loading dock covers and proper location	Municipal fleet maintenance
Chemical Handling and Storage	Road salt application and storage
Spill control plans	**Containment and Diversion**
Proper hazardous materials and chemical storage	Sediment and erosion control

Nonstructural practices chosen by the user to be implemented on a site need to have their implementation methods documented and assured, such as in a covenant with the City to ensure that all required maintenance or actions are being performed as needed. Any reduction in runoff volume or pollutant load as a result of these practices needs to be determined by the user and approved by the City.

Step 3 – Selection of Structural BMPs

Preferred BMP options at this stage of the selection process may include incorporating structural BMPs, retrofits to an existing structural BMP, or the use of nonstructural measures or the modification of an existing nonstructural BMP program. It is possible that some combination of these may be the preferred method of achieving a particular objective. In the final selection process the preferred BMPs are evaluated based their construction costs, maintenance requirements, and ability to gain management and community support. This evaluation will result in an alternative that will reflect the unique features of a particular site.

Construction Costs and Maintenance Requirements

The cost for building and maintaining a BMP or series of BMPs is important in selecting post construction BMPs. Estimates of construction and O&M costs are provided in Tables 6.6 and 6.7. The costs provided in the tables are from available historical references, and can be used to provide relative costs for comparative purposes only.

Table 6.7
Estimated Construction Costs and Annual O&M
Storm Water Best Management Practices Technical Manual
Auburn, Indiana

BMP Group	BMP	Estimated Construction Costs [1]	Range of Estimated Construction Costs [5] (Drainage Area in Ha)	Estimated Annual O&M Person-Hours
Detention / Retention Systems	Detention Ponds	$49,000[1a]	$200,000–$1,000,000 (11.9–33.1)	136 – 570 [6]
	Detention Tanks	$25,000[1a]	$13,000 per hectare [4]	160 [4]
	Retention Ponds	Use Same as Detention Pond		160 [4]
	Wetlands	$25,000 [1a,4]		200 – 600 [4]
Infiltration Systems	Infiltration Trench	$58,000[1a]	$235,000–$260,000 (4.2)	70 [6]
	Infiltration Basin	$10,000[1a]	$282,000–$323,000 (7.9–10.4)	193 [6]
Filtering Systems	Underground Sand Filters	$47,000[1b]	$8,000 - $40,000 [4] (1 – 5)	145 [4]
	Surface Sand Filters	$54,000[1b]	$6,000 - $30,000 [4] (1 – 5)	93 [6]
	Organic Media Filters	$54,000[1b]	$271,000–$563,000 (2.0–6.9)	72 [6]
	Bioretention	$34,000[1b]	$35,000 per hectare	60 [4]
Vegetated Swales and Filter Strips	Vegetated Swales	$5,000[1c]	$69,000–$188,000 (0.5–5.9)	211 [6]
	Vegetated Filter Strips	$6,800[1c]	$117,000 (1.2)	202 [6]
	Level Spreaders	$500 [2]	$300–$1,000 [4]	50 [4]
Water Quality Inlets	Catch Basin Inserts	$2,100 per unit	$2,100 per unit	24/unit [4]
	Oil-Grit Separators	$21,000[1c]	$209,000 (2.0)	139 [6]
	Manufactured Systems	Variable	Variable	Variable
Low Impact Development	Porous Pavement	Normal pavement costs + 150% [2]	$45,000-$100,000/acre	200 [4]
	Green Roofs	$14,000 [3]	$5-$15/square foot	15 [2]
	Rain Gardens	$11,000 [3]	$5-$10/square foot	40 [4]
	Rain Barrels / Cisterns	$100 (rain barrel) [4]	$400-$5,000/cistern	0-4 [4]
	Tree Box Filters	$9,500 [4]	$8,000-$15,000	10 [4]

Notes:
[1] Unless noted otherwise, as adapted from FHWA, 2000, *Storm Water Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring*, Office of Natural Environment, USDOT, Washington, DC. Costs were originally reported in 1995 dollars; costs are expressed in 2005 dollars based on ENR CCI averages for 1995 (ENR CCI = 5,471) and 2005 (ENRCCI = 7,446).
[1a] Cost for treating 280 m^3 of runoff = 0.5 inches of rain on 2 hectares; as adapted from FHWA, 2000. Costs are expressed in 2005 dollars based on ENR CCI.
[1b] and [1c] Cost per hectare served; as adapted from FHWA, 2000. Costs are expressed in 2005 dollars based on ENR CCI.
[2] Per 100 Linear Feet in 2005 dollars.
[3] Per 1,000 Square Feet in 2005 dollars.
[4] Costs and person-hours as estimated by Symbiont. Costs are estimated in 2005 dollars.
[5] Unless noted otherwise, as adapted from Currier et. al., 2001, *California Department of Transportation BMP Retrofit Pilot Program*, Presented at Transportation Research Board, Washington, DC, Jan 7-11, 2001. Costs were originally reported in 2001 dollars; costs are expressed in 2005 dollars based on ENR CCI annual averages for 2001 (ENR CCI= 6,343) and 2005 (ENR CCI = 7,446). Cost includes items that are monitoring related, such as flumes, concrete pads, and equipment enclosures, except for drain inlet inserts.
[6] As adapted from Currier et. al.

Table 6.8 Estimated Construction Cost Formulas[1] Storm Water Best Management Practices Technical Manual Auburn, Indiana		
BMP Group	**BMP**	**Formula to Estimate Cost**
Detention / Retention Systems	Detention Ponds[2A]	C = 229.16 x (V x 0.69) V is pond storage volume (m^3) up to crest of emergency spillway.
	Detention Tanks[2]	$C = 51.85 (D / 0.02832)^{0.6816}$ D = volume of storage for the maximum design event in m^3
	Retention Ponds	Use Same as Detention Pond
	Wetlands	$C = 30.6V^{0.705}$ V is wetland volume needed to control the 10-year storm (ft^3).
Infiltration Systems	Infiltration Trench[2]	$C=1792.44 V^{0.63}$ V is storage volume in m^3
	Infiltration Basin[2]	$C = 18.92 (V / 0.02832)^{0.69}$ V is volume of storm water treated in m^3
Filtering Systems	Underground Sand Filters[3]	$19,000 per impervious acre served
	Surface Sand Filters[3]	$4,600 – $22,000 per impervious acre served
	Organic Media Filters[3]	$4,600 – $22,000 per impervious acre served
	Bioretention[2]	C = 14,000 x A A is total impervious area in acres
Vegetated Swales and Filter Strips	Vegetated Swales[4]	$7 and $22 per linear foot
	Vegetated Filter Strips[2]	$2,900 per acre
	Level Spreaders	$5.00 per linear foot
Water Quality Inlets	Catch Basin Inserts	$100 - $1,500
	Oil-Grit Separators[4]	$7,500 to $22,000
	Manufactured Systems	Variable
Low Impact Development	Porous Pavement	Normal pavement costs + 150%
	Green Roofs	$5-$15 per square foot [5]
	Rain Gardens	$5-$10 per square foot [5]
	Rain Barrels / Cisterns	$100-$150 per rain barrel
	Tree Box Filters	$8,000 materials, $1,500 installation

Notes:

[1] Unless noted otherwise, as adapted from FHWA, 2000, *Storm Water Best Management Practices in an Ultra- Urban Setting: Selection and Monitoring*, Office of Natural Environment, USDOT, Washington, DC.

[2] Cost were originally expressed in 1995 dollars; costs are expressed in 2005 dollars based on ENR CCI annual averages for 1995 (ENR CCI = 5,471) and 2005 (ENR CCI = 7,446).

[2a] Cost were originally expressed in 1995 dollars; costs are expressed in 2005 dollars based on ENR CCI annual averages for 1995 (ENR CCI = 5,471) and 2005 (ENR CCI = 7,446). (FHWA, 2000) suggests increasing cost by 25% for contingency.

[3] Cost were originally expressed in 1994 dollars; costs are expressed in 2005 dollars based on ENR CCI annual averages for 1994 (ENR CCI = 5,408) and 2005 (ENR CCI = 7,446).

[4] Cost were originally expressed in 1992 dollars; costs are expressed in 2005 dollars based on ENR CCI annual averages for 1992 (ENR CCI = 4,985) and 2005 (ENR CCI = 7,446).

[5] Cost estimated by Symbiont in 2005 dollars.

Management and Community Support

The final step in selecting structural BMPs is to assess community and environmental factors involved in BMP implementation. Table 6.8 scores each BMP on a scale of low, medium, or high for each factor described below.

- *Maintenance*. Assesses the relative maintenance effort needed for an BMP, in terms of three criteria: frequency of scheduled maintenance, chronic maintenance problems (such as clogging) and reported failure rates. It should be noted that all BMPs require routine inspection and maintenance.

- *Community Acceptance*. Assesses community acceptance, as measured by three factors; market preference surveys, reported nuisance problems, and visual orientation. It should be noted that a low rank can often be improved by better landscaping.

- *Affordability*. Ranks BMPs according to their relative construction cost per impervious acre treated. These costs exclude design, land acquisition, and other costs.

- *Safety*. Compares the relative safety of a BMP. ‘Low’ indicates a safe BMP, while ‘High’ indicates deep pools may create potential safety concerns. The safety factor is included at this stage of the process because liability and safety are of paramount concern in many residential settings.

- *Habitat*. Evaluates BMPs on their ability to provide wildlife or wetland habitat, assuming that an effort is made to landscape them appropriately. Objective criteria include size, water features, wetland features, and vegetative cover of the BMP and its buffer.

Table 6.9
Community and Environmental Factors
Storm Water Best Management Practices Technical Manual
Auburn, Indiana

BMP Group	BMP Design	Ease of Maintenance	Community Acceptance	Affordability	Safety	Habitat
Detention / Retention Systems	Detention Pond	H	H	H	M	M
	Detention Tank	H	M	M	H	L
	Retention Pond	H	H	M	M	H
	Wetland	M	M	M	M	H
Infiltration Systems	Infiltration Trench	L	H	M	L	L
	Infiltration Basin	L	L	M	L	L
Filtering Systems	Underground Sand Filter	L	H	L	M	L
	Surface Sand Filter	M	M	L	L	L
	Organic Media Filter	M	H	L	L	L
	Bioretention	M	M	M	L	M
Vegetated Swales and Filter Strips	Vegetated Swale	H	M	H	L	M
	Vegetated Filter Strips	M	M	L	L	M
	Level Spreader	M	M	M	L	L
Water Quality Inlets	Catch Basin Inlets	M	M	L	H	L
	Oil-Grit Separators	M	M	M	H	L
	Other Manufactured Systems	L-H	M	L-H	H	L
Low Impact Development	Porous Pavement	M	M	H	H	L
	Green Roofs	M	M	H	M	M
	Rain Gardens	L	M	L	L	M
	Rain Barrels / Cisterns	L	M	L	L	L
	Tree Box Filters	M	M	M	L	M

H = High
M = Medium
L = Low
Source: Adapted from CWP, 2000 and others.

Section 7.0
TYPES AND DESIGN EXAMPLES OF POST CONSTRUCTION STRUCTURAL BMPs

This section includes a basic overview discussion of the types and designs of post construction structural BMPs. Structural BMPs are generally designed to remove constituents in storm water runoff. Checklists for the construction and operation and maintenance of some of the general categories of structural BMPs are included in Appendices E and F. Structural BMP factsheets are included in Appendix G.

Additional details about each BMP are included in the fact sheets in Appendix G and should be referenced when choosing and designing each BMP. Sample construction specifications and additional design examples can be found at the website of the Storm Water Manager's Resource Center (SMRC) (www.stormwatercenter.net) developed by the Center for Watershed Protection. Other references may also be found and used.

The following sections will detail the type(s), design requirements, and guidelines for the structural BMPs, which include:

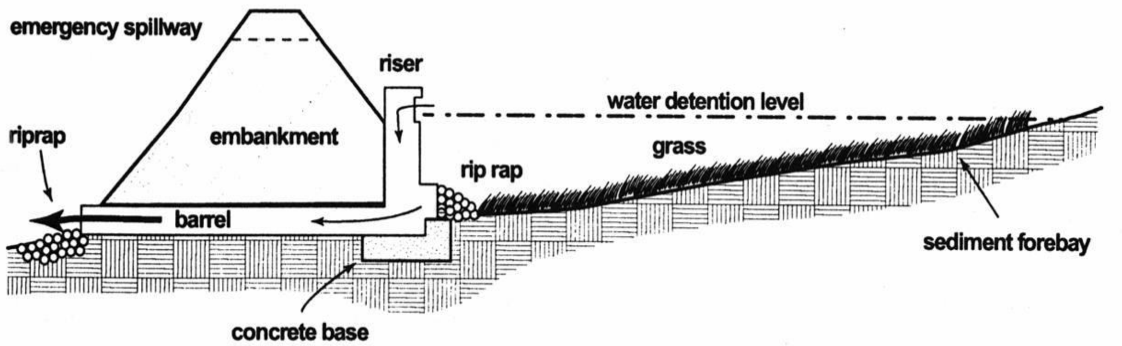
- Detention/Retention Systems
- Infiltration Systems
- Filtering Systems
- Vegetated Swales/Filter Strips
- Water Quality Inlets
- Low Impact Development

7.1 STRUCTURAL BMP DETAIL: DETENTION/RETENTION SYSTEMS

7.1.1 Types

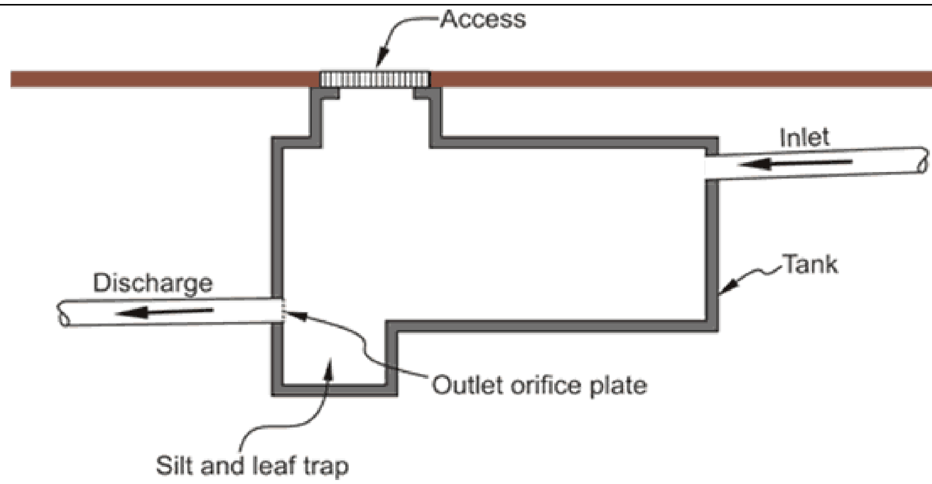
Detention/Retention Systems are practices that could have a combination of a detention volume, permanent pool, and/or shallow marsh equivalent to the entire WQ_v. Wetlands use marsh areas to treat urban storm water and often incorporate small permanent pools and/or extended detention storage to achieve the full WQ_v. Detention/Retention Systems can also be used to provide channel protection volume control as well as overbank and extreme flood attenuation. Various BMP types are shown in the following figures.

Figure 7.1.1 Detention Pond Profile



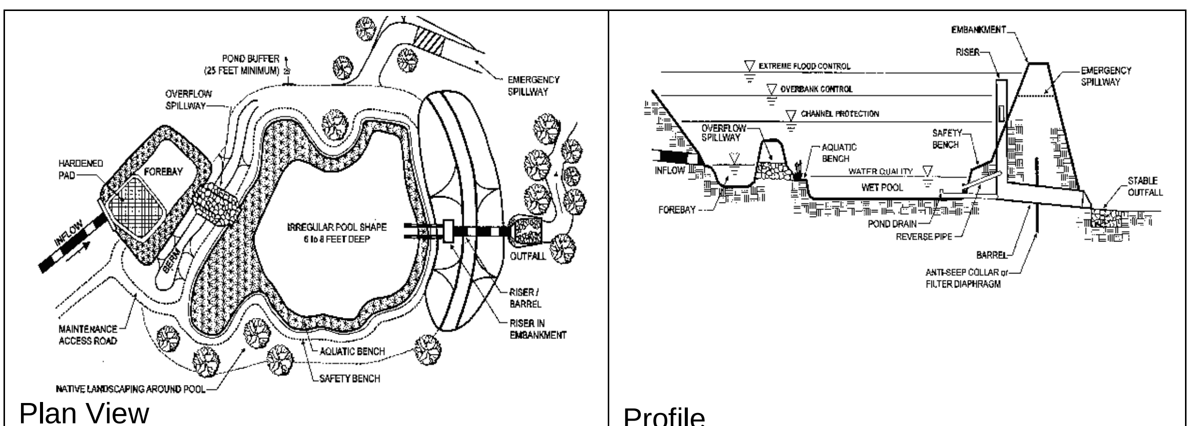
Source: USEPA

Figure 7.1.2 Detention Tank Profile



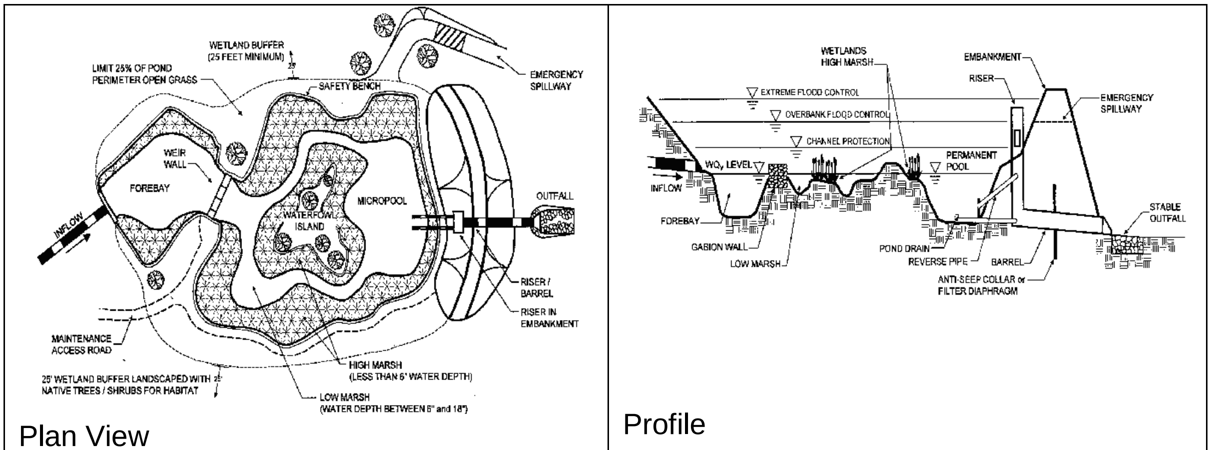
Source: New Zealand Water Environment Research Foundation

Figure 7.1.3 Retention Pond



Adapted from CWP, 2000

Figure 7.1.4 Wetland



Adapted from CWP, 2000

7.1.2 Design Requirements and Guidance

Table 7.1
Design Criteria: Detention/Retention Systems
Storm Water Best Management Practices Technical Manual
Auburn, Indiana

Required Elements	**Guidance**
Feasibility	
• Contributing drainage area • Dam safety review • Jurisdictional wetlands restrictions	• Thermal impacts for cold water streams • Water balance
Conveyance	
• Forebay at each inlet • Channel stabilization downstream • Minimum Flow Path	• Watertight joints on concrete spillways • Inlet pipes partially submerged • Outlet configuration • Features to minimize stream warming at the outfall • Pond liner guidance • Microtopography
Pretreatment	
• Forebay at inlet • Forebay volume • Access to forebay • Micropool at outlet	• Other specific forebay design elements
Treatment	
• Water quality volume provided • Minimum length to width ratio • At least 50% of water quality storage in permanent pool for the Wet ED design. • Minimum surface area/ drainage area ratio.	• Off-line design • Multiple cells and treatment pathways • General guidance on maximum flow path and microtopography

Table 7.1
Design Criteria: Detention/Retention Systems
Storm Water Best Management Practices Technical Manual
Auburn, Indiana

Required Elements	Guidance
• ED no greater than 50% of entire Wq_v • Specific depth zone breakdown (e.g., fraction in deep water versus shallow zones).	
Landscaping	
• Safety and aquatic benches • Landscaping plan needed. • Pond buffer • No woody vegetation near embankment or spillway • Wetland buffer • Restrictions on donor plant material from natural wetlands.	• Wetland plants incorporated • Guidance to enhance plant survival. • Preserve existing trees • Specific features of the landscaping plan. • Guidance for wetland establishment
Maintenance	
• Legally binding maintenance agreement • Sediment removal from forebay • Provide a maintenance easement an right-of-way • Removable trash rack. • Minimum requirements for a non-clogging low flow orifice • Riser in the embankment. • Pond drain required. Notification required for pond drainage. • Gate valve on pond drain, and location of the valve. • Riser safety features. • Reinforcement plantings after second season.	• Guidance on sediment disposal • Specific maintenance access design • Design options for the low flow orifice. • Riser access guidance. • Guidance for pond draining. • Designs of valve controls to prevent vandalism • Pond fencing not desirable • Internal side slopes • Warning signs near ponds. • Guidance on maintenance in regards to wetlands laws.
Source: Adapted from CWP, 2000.	

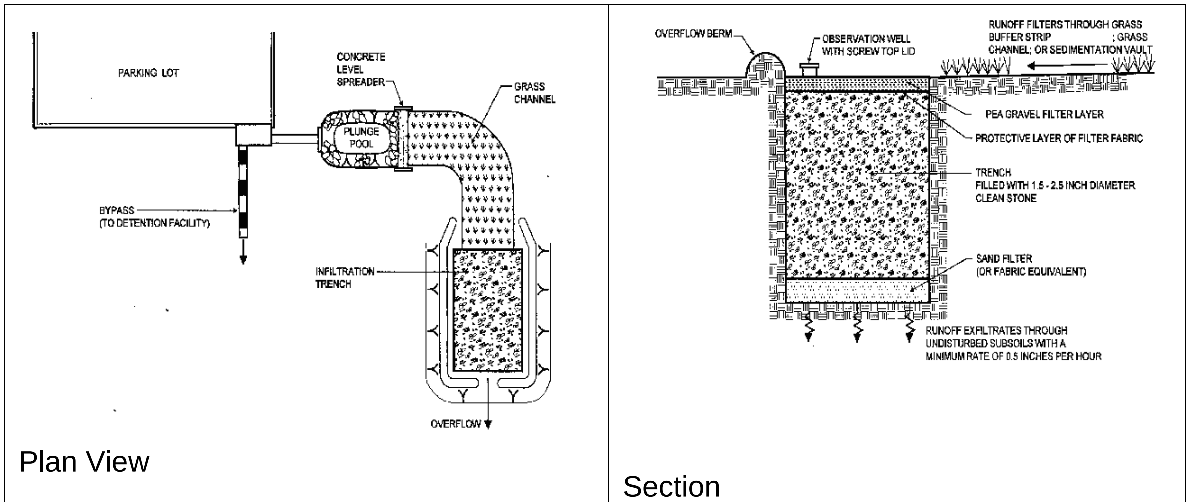
7.2 STRUCTURAL BMP DETAIL: INFILTRATION SYSTEMS

7.2.1 Types

Storm water infiltration practices capture and temporarily store storm water before allowing it to infiltrate into the soil over a 2-day period. Design variants include:

- Infiltration Trench (Figure 7.2.1)
- Infiltration Basin (Figure 7.2.2)

Figure 7.2.1 Infiltration Trench

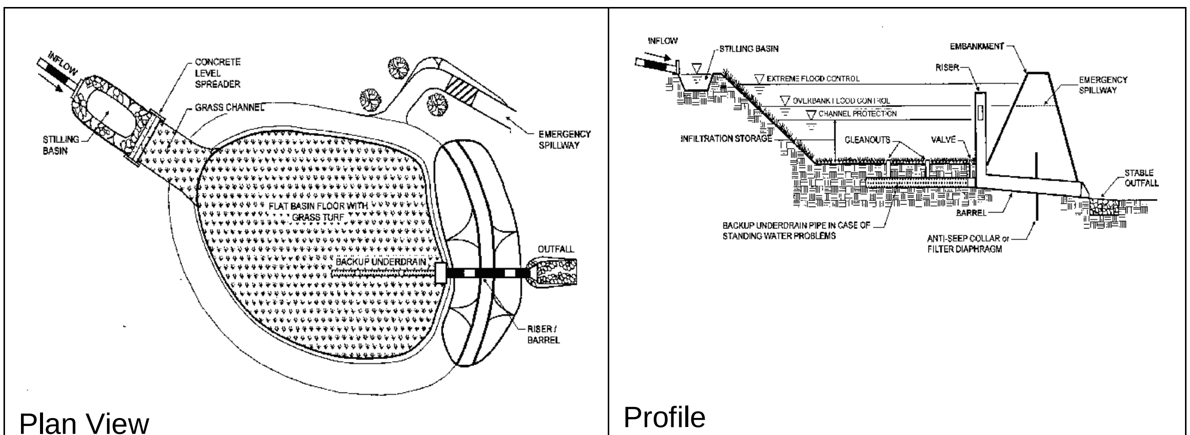


Plan View

Section

Adapted from CWP, 2000

Figure 7.2.2 Infiltration Basin



Plan View

Profile

Adapted from CWP, 2000

7.2.2 Design Requirements and Guidance

Infiltration practices are an excellent technique for meeting recharge, storm water detention, and channel protection requirements in certain limited cases. Extraordinary care can be taken to assure that long-term infiltration rates are achieved through post construction inspections and long-term maintenance.

Table 7.2.1 Design Criteria: Infiltration Storm Water Best Management Practices Technical Manual Auburn, Indiana	
Required Elements	**Guidance**
Feasibility	
• Minimum infiltration rate • Restrictions on fill soils • No hotspot runoff • Prohibited in some geography • Separation from groundwater • Separation from water supply • Setback from structures • Soil textures	• Maximum drainage area should be checked for each practice to not exceed infiltration capacity.
Conveyance	
• Non-erosive flow exceeding practice • Maximum dewatering time • Off-Line	• Overflows for larger storm events
Pretreatment	
• Minimum volume • Non-erosive flow leaving pretreatment	• Redundant pretreatment • Line with filter fabric
Treatment	
• Water quality volume • Construction sequence to maximize practice life	• Best used with other practices • Porosity for stone reservoirs
Landscaping	
• Dense vegetative cover on contributing drainage • Construct after vegetation is established	
Maintenance	
• Never serves as a sediment control device • Observation well • Maintenance access • Not covered with an impermeable surface	• Accommodate dewatering devices in case of failure • OSHA requirements may apply to trench construction
Source: Adapted from CWP, 2000.	

Table 7.2.2 **Minimal Site-Requirement Criteria For Infiltration** **Storm Water Best Management Practices Technical Manual** **Auburn, Indiana**
• Infiltration rate (fc) greater than or equal to 0.5 inches per hour. • Soils have a clay content less than 20% and a silt/clay content of less than 40%. • Infiltration cannot be located on slopes greater than 6% or in fill soils. • Hotspot runoff should not be infiltrated. • The bottom of the infiltration facility must be separated by at least 2 feet vertically from the seasonally high water table to bedrock. • Infiltration facilities must be located at least 100-feet horizontally from any water supply well. • Maximum contributing area generally less than 5 acres. • Setback 25-feet down-gradient from structures.
Source: Adapted from CWP, 2000.

If infiltration is feasible, obtain the necessary site-specific topographic and soil characteristics as shown in Table 7.2.2.

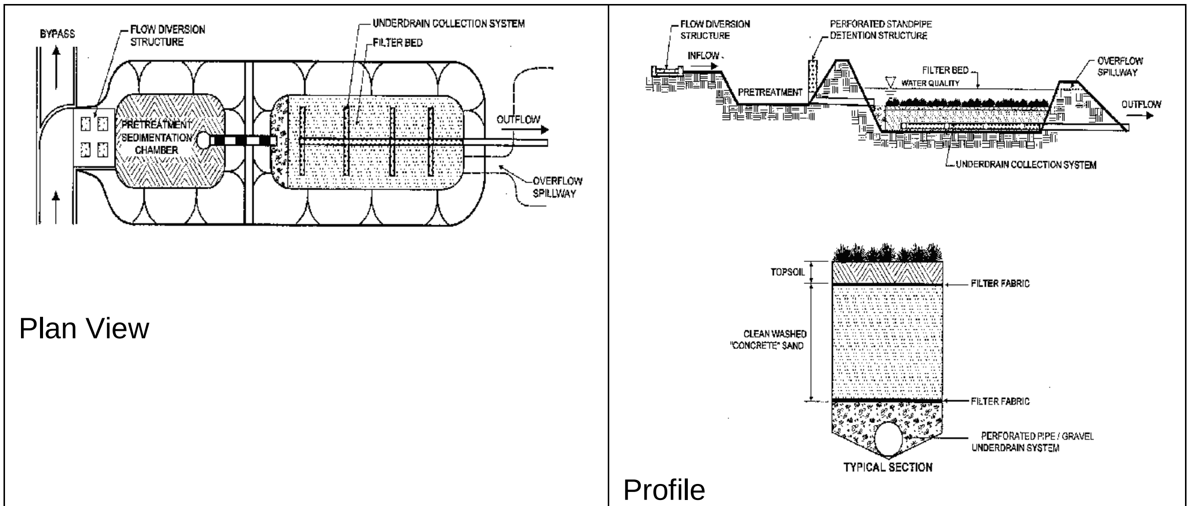
7.3 STRUCTURAL BMP DETAIL: FILTERING SYSTEMS

7.3.1 Types

Storm water filtering system capture and temporarily store the WQ_v and pass it through a filter bed of sand, organic matter, soil or other media. Filtered runoff may be collected and returned to the conveyance system, or allowed to partially exfiltrate into the soil. Design variants include:

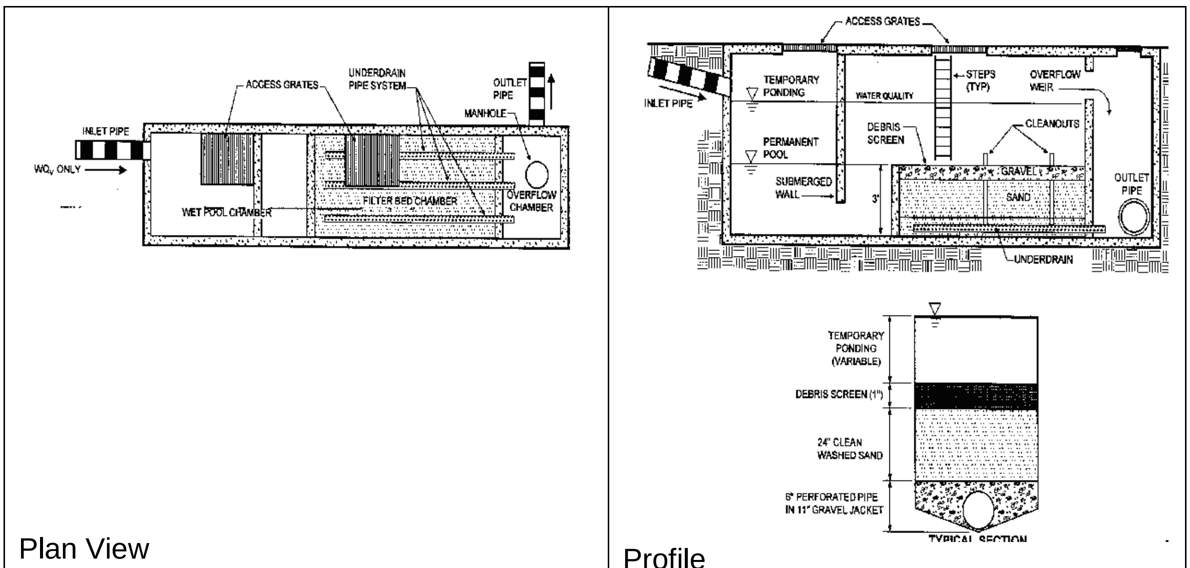
- Surface Sand Filter (Figure 7.3.1)
- Underground Sand Filter (Figure 7.3.2)
- Organic Media Filter (Figure 7.3.3)
- Bioretention (Figure 7.3.4)

Figure 7.3.1 Surface Sand Filter



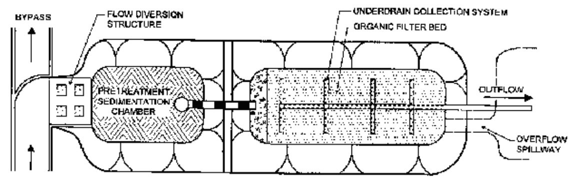
Adapted from CWP, 2000

Figure 7.3.2 Underground Sand Filter

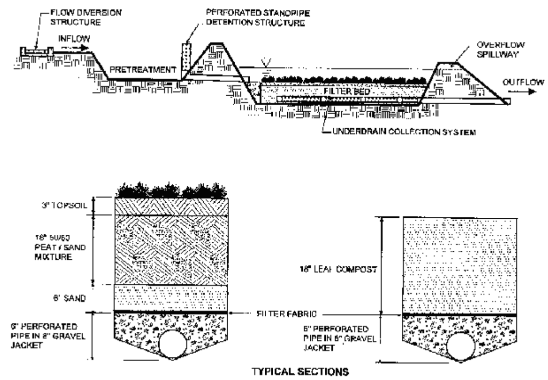


Adapted from CWP, 2000

Figure 7.3.3 Organic Media Filter



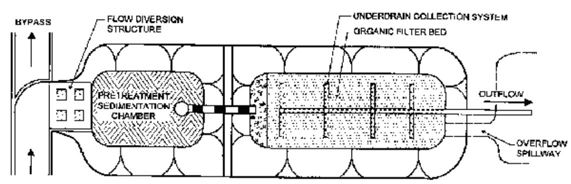
Plan View



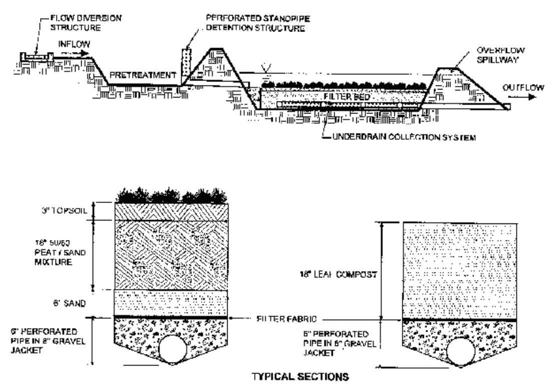
Profile

Adapted from CWP, 2000

Figure 7.3.4 Bioretention



Plan View



Profile

Adapted from CWP, 2000

7.3.2 Design Requirements and Guidance

Filtering systems should not be designed to provide storm water detention or channel protection except under extremely unusual conditions. Filtering practices should generally be combined with a separate BMP to provide those controls. Filtering systems could be used to meet recharge requirements if they are designed to exfiltrate into the soil.

Table 7.3 Design Criteria: Filtering Systems Storm Water Best Management Practices Technical Manual Auburn, Indiana	
Required Elements	**Guidance**
Feasibility	
	Head requirements Maximum drainage area Best applied to highly impervious land uses.
Conveyance	
• Off-line design if delivered by stormdrain • Overflow for ten-year storm • Flow regulator to divert WQ_v to the practice • Underdrain	
Pretreatment	
• Pretreatment volume • Pretreatment sizing	
Treatment	
• Sizing methods • Minimum volume in practice • Filter bed depth • Filter media specifications	• Typically cannot provide flood control or channel protection • Filter depth
Landscaping	
• Contributing area stabilized • Landscaping plan for bioretention	• Grass species guidance for grass-covered filters • Bioretention planting guidelines
Maintenance	
• Sediment chamber outlet device repair • Sediment chamber sediment clean-out • Maintain drop at bioretention inlets • Access to pretreatment and filter bed	• Maximum vegetation depth in sediment chamber • Mowing
Source: Adapted from CWP, 2000.	

7.4 STRUCTURAL BMP DETAIL: VEGETATED SWALES AND FILTER STRIPS

7.4.1 Types

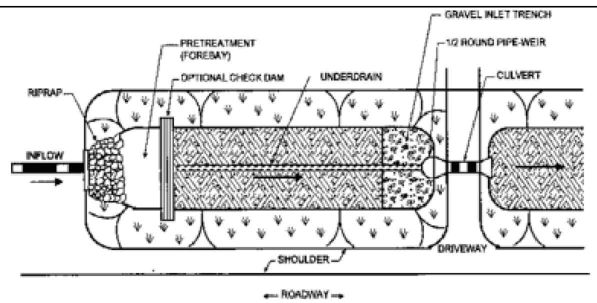
Vegetated swales are explicitly designed to capture and treat the full volume of storm water within dry or wet cells formed by check dams or other means. Design variants include:

- Vegetated Swale – Dry (Figure 7.4.1)
- Vegetated Swale – Wet (Figure 7.4.2)

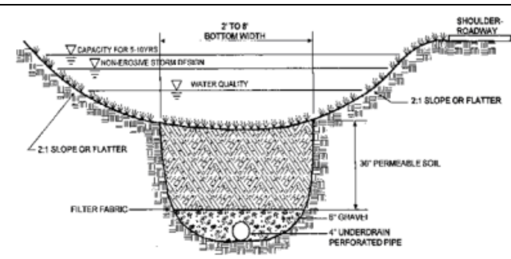
Vegetated filter strips and level spreaders are other variations of a filtering system where the flow crosses the structure and is not carried by it. Vegetated filter strips are often used along with another BMP to provide additional pretreatment. Level Spreaders are often used before filter strips to even out the flow along the length of the BMP.

- Vegetated Filter Strip (Figure 7.4.3)
- Level Spreader (Figure 7.4.4)

Figure 7.4.1 Vegetated Swale – Dry



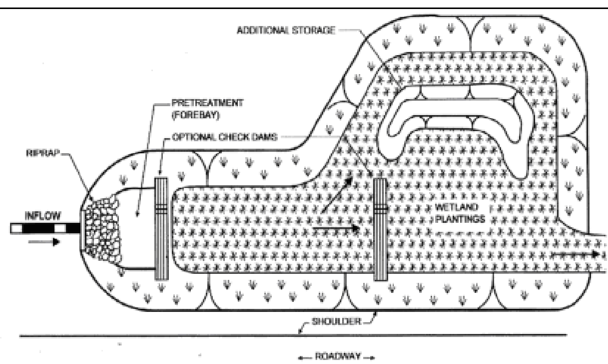
Plan View



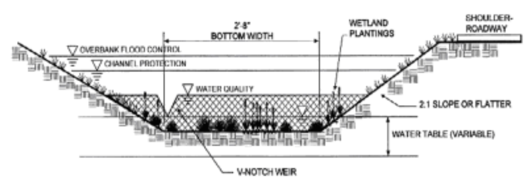
Section

Adapted from CWP, 2000

Figure 7.4.2 Vegetated Swale – Wet



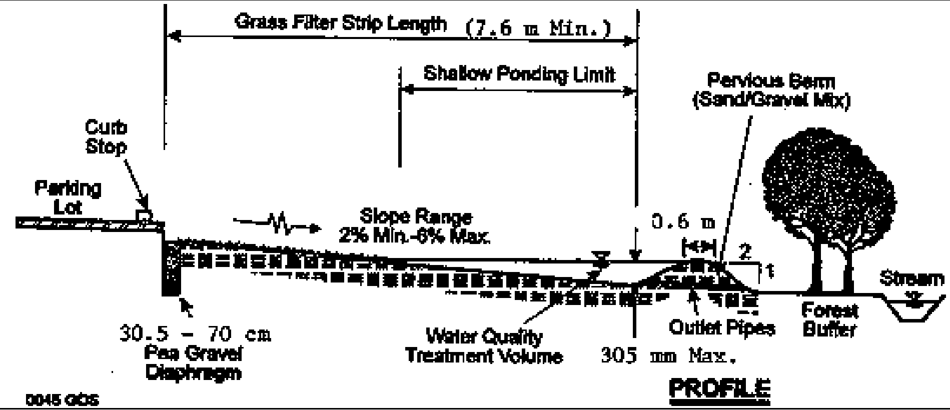
Plan View



Section

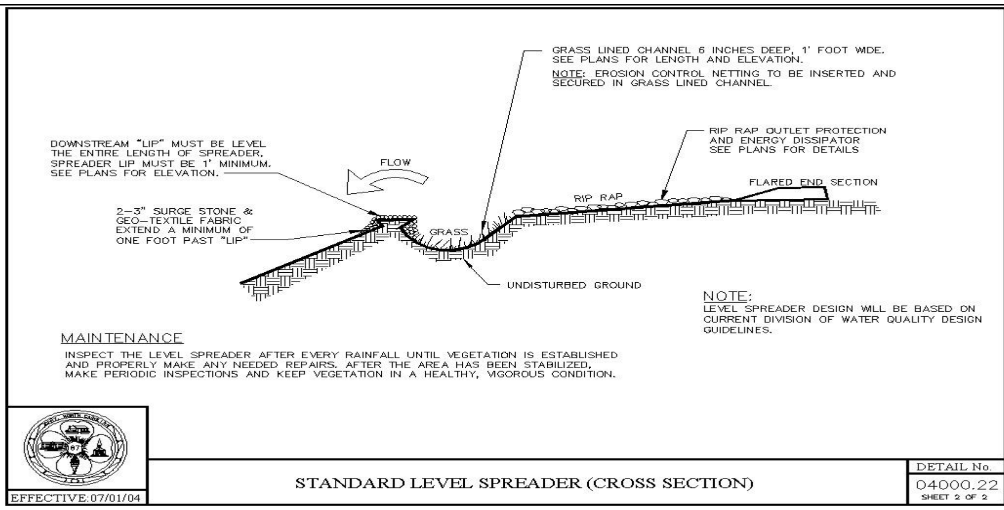
Adapted from CWP, 2000

Figure 7.4.3 Vegetated Filter Strip



Adapted from FHWA – Ultra Urban BMP Study

Figure 7.4.4 Level Spreader



Plan View

Adapted from Town of Cary, NC

7.4.2 Design Requirements and Guidance

Vegetated swales and filter strips should not be designed to provide storm water detention or channel protection. Filtering practices must generally be combined with a separate facility to meet these requirements. Open channel design criteria are listed in Table 7.4.1.

Table 7.4.1 Design Criteria: Vegetated Swales and Filter Strips Storm Water Best Management Practices Technical Manual Auburn, Indiana	
Required Elements	**Guidance**
Feasibility	
• Maximum longitudinal slopes	• Best land uses
Conveyance	
• Non-erosive storms • Save conveyance • Maximum side slopes • Maximum ponding time • Underdrain for dry swale	• Pea gravel shelf at inlets
Pretreatment	
• Pretreatment volume • Treat direct concentrated flow	• Treat lateral flows with a pea gravel diaphragm
Treatment	
• Store water quality volume, or maintain for a specific time period • Maximum bottom width	• Maximum ponding depth
Landscaping	
	• Land use • Grass and wetland plant types specified
Maintenance	
• Sediment removal	• Mowing frequency
Source: Adapted from CWP, 2000	

7.5 STRUCTURAL BMP DETAIL: WATER QUALITY INLETS

7.5.1 Types

Water quality inlets include manufactured systems or structures typically supplied by a vendor and are proprietary. A wide variety of styles and types exist and the user should be cautioned to check references and look for independent verification of removal efficiencies. Two types of water quality inlet BMPs with fact sheets included in this manual are catch basin inserts and oil-grit separators. Many manufacturers make each of these BMPs and the user should investigate the best type for the site in questions. Other types of systems include vortex separators and various forms of filters.

7.5.2 Design Requirements and Guidance

After the BMP is approved by the City, manufacturers' instructions should be followed for each of the BMPs for sizing, installation, and maintenance.

7.6 STRUCTURAL BMP DETAIL: LOW IMPACT DEVELOPMENT

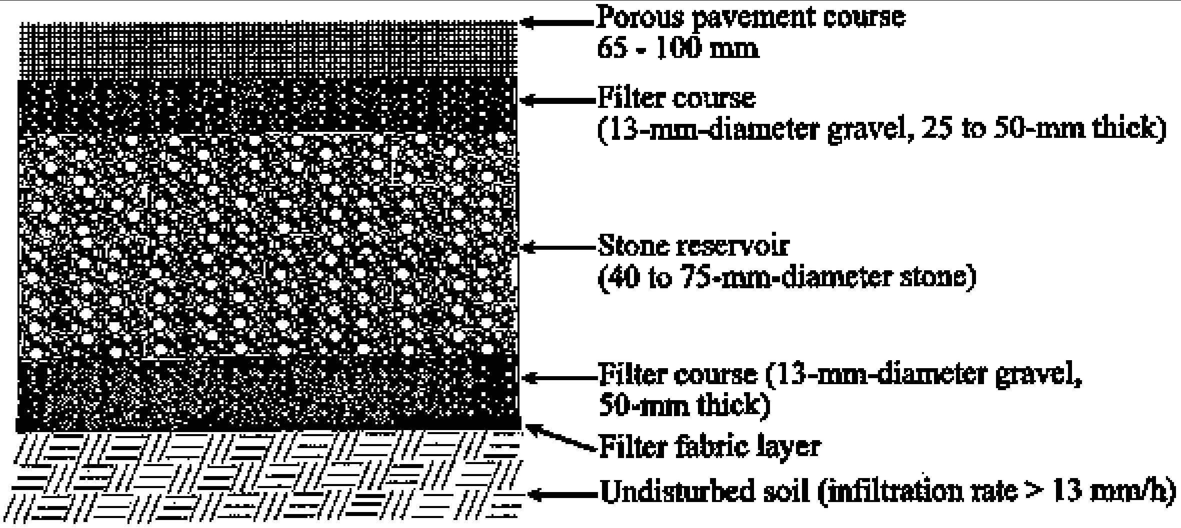
The City encourages the use of Low Impact Development (LID) practices throughout the City of Auburn to minimize the amount of runoff that needs to be managed and treated either on site or by the City. Many practices exist that allow for more environmentally friendly developments and the user is encouraged to research any additional options that may be applicable to each site.

7.6.1 Types

There are many types of LID practices in use around the country. Five practices are presented in this manual: porous pavement, green roofs, rain gardens, rain barrels / cisterns, and tree box filters.

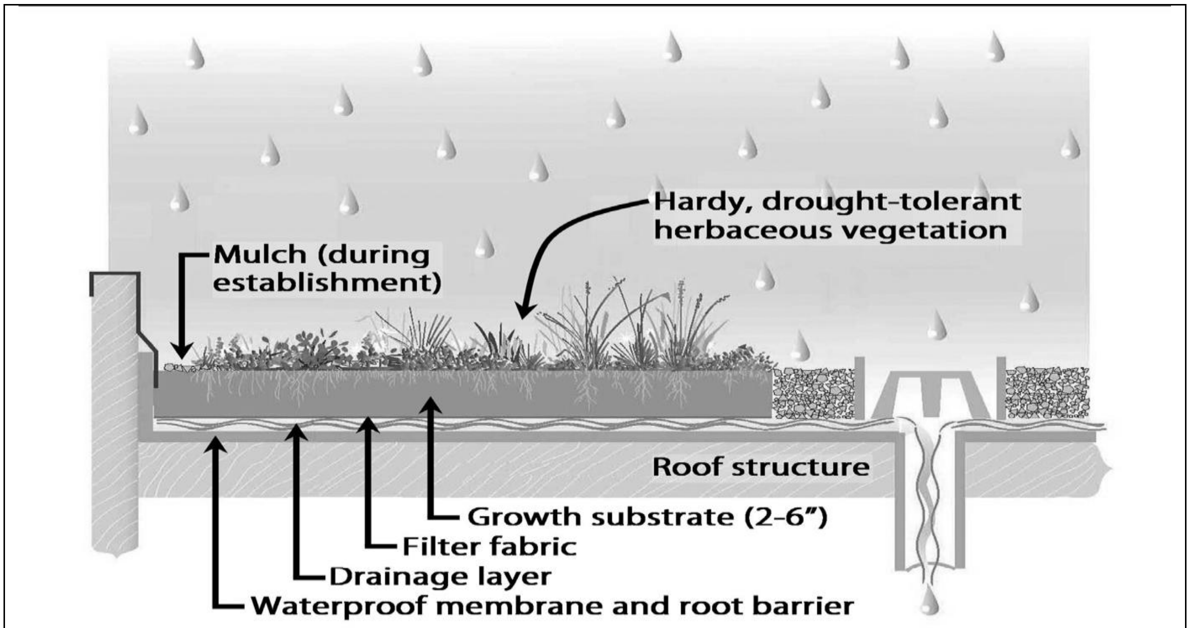
- Porous Pavement (Figure 7.6.1)
- Green Roof (Figure 7.6.2)
- Rain Garden (Figure 7.6.3)
- Rain Barrels / Cistern (Figure 7.6.4)
- Tree Box Filter (Figure 7.6.5)

Figure 7.6.1 Porous Pavement



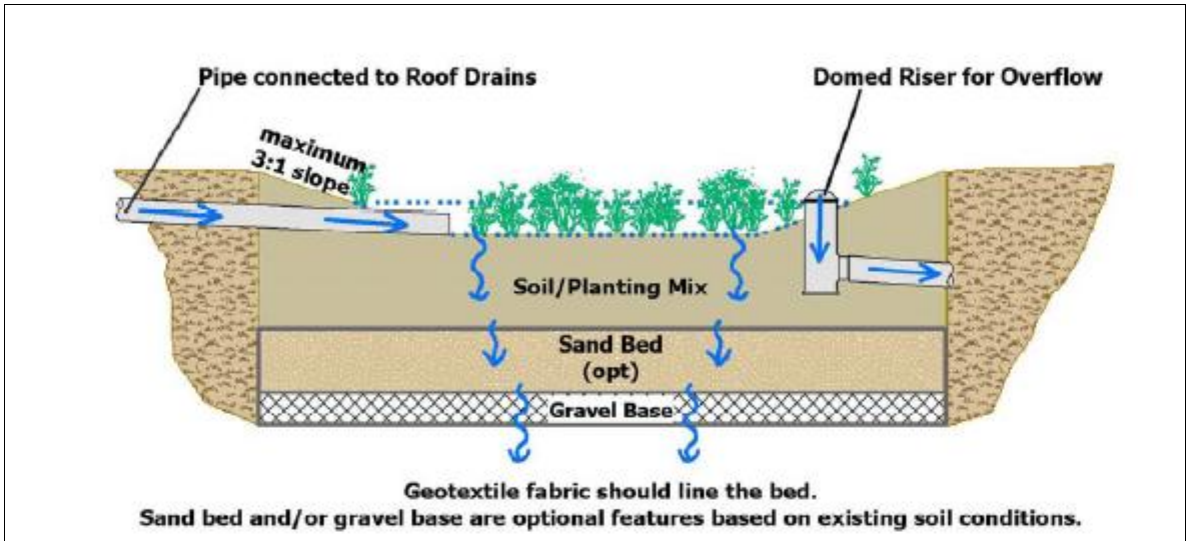
Source: FHWA

Figure 7.6.2 Green Roof



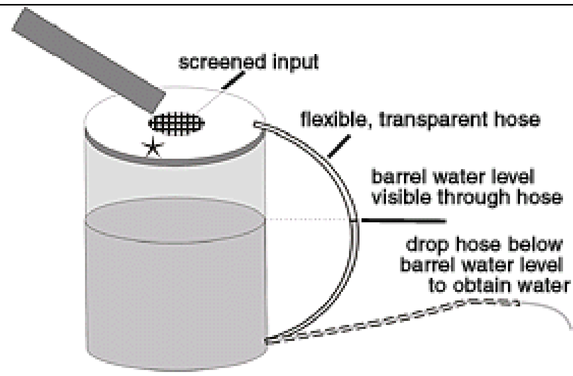
Source: MA Metropolitan Area Planning Council

Figure 7.6.3 Rain Garden



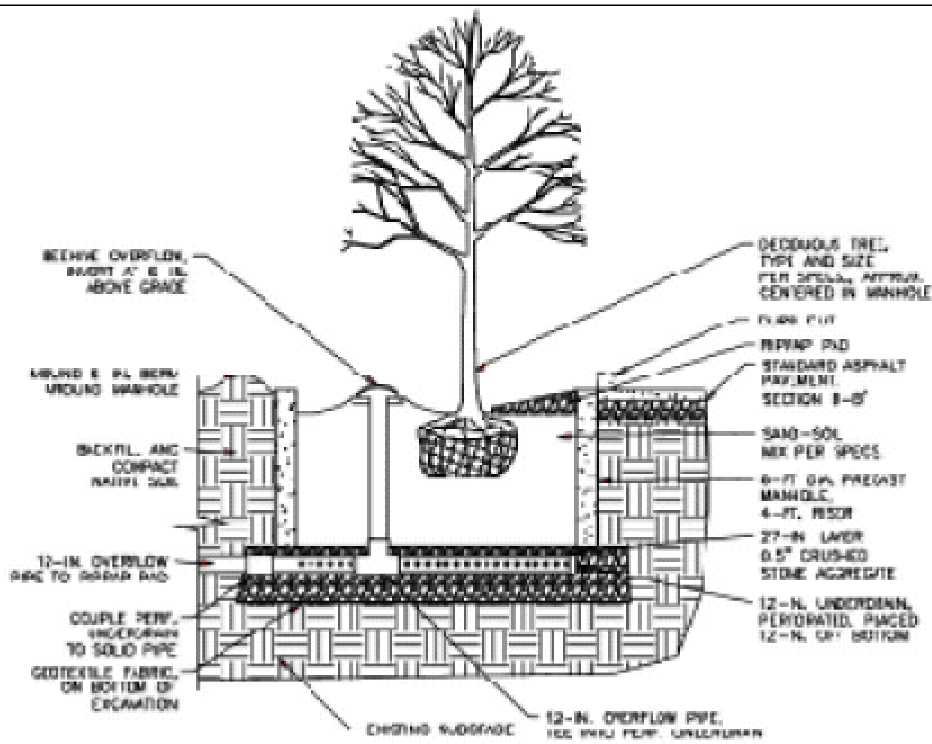
Source: Pennsylvania Storm Water Management Manual

Figure 7.6.4 Rain Barrel



Source: LID Development Center

Figure 7.6.5 Tree Box Filter



Source: Environmental Research Group – University of New Hampshire

7.6.2 Design Requirements and Guidance

Proper Maintenance is essential for low impact development practices. Specific design information and guidance can be found in the fact sheets located in Appendix G.

7.7 PROCEDURE FOR USE OF OTHER BMPs

Other BMPs can be employed at a site if the user has a BMP that has removal efficiencies that have been verified independently of the manufacturer. The user would need to propose the BMP to the City of Auburn MS4 Operator and provide all necessary information requested by the MS4 Operator. The BMP must be approved by the City of Auburn MS4 Operator.

Section 8.0
REFERENCES

Center for Watershed Protection, Inc., 2000, *Storm Water Manager's Resource Center (SMRC) Website,* Available www.stormwatercenter.net, Ellicott City, MD

Federal Highway Administration, 2000, *Storm Water Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring*, Office of Natural Environment, USDOT, Washington, DC

Huff, Floyd A. and Angel, James R., Rainfall Frequency Atlas of the Midwest Bulletin 71, Midwestern Climate Center – Illinois State Water Survey, 1992

Natural Resources Conservation Service, Urban Hydrology for Small Watersheds – Technical Release No. 55, June 1986

Puget Sound Action Team and Washington State University, Low Impact Development Technical Guidance Manual for Puget Sound, Publication No. PSAT 05-03, January 2005

Other References are listed with select Tables/Figure or on the BMP Factsheets

APPENDICES

APPENDIX A

CITY OF AUBURN
POST CONSTRUCTION
STORM WATER RUN-OFF CONTROL
ORDINANCE

1st Reading____________
2nd Reading____________

ORDINANCE NO. 2006-_____

AN ORDINANCE FOR CONSTRUCTION SITE STORM WATER RUNOFF CONTROL

SUMMARY

This Ordinance regulates construction site storm water runoff within the Municipal City of Auburn. This ordinance proposes to promote public welfare by guiding, regulating, and controlling the design, construction, use, and maintenance of any development or any other activity that disturbs or breaks the topsoil or results in the movement of earth on land in the City of Auburn.

____________ Recorder's Office

____________ Auditor's Office

____________ Clerk's Office

____________ Other

____

____

____

____

__________ Publish Public Hearing

____

__________ Publish O/R after adoption

1[st] Reading____________
2[nd] Reading____________

ORDINANCE NO. 2006-____

AN ORDINANCE FOR CONSTRUCTION SITE STORM WATER RUNOFF CONTROL.

BE IT ORDAINED BY THE COMMON COUNCIL OF THE CITY OF AUBURN, INDIANA.

Section I.

That the following attached Exhibit "A" shall be adopted as an Ordinance of the Municipal City of Auburn, Indiana, codified, and placed on the City of Auburn, Indiana internet site.

Section II.

BE IT FURTHER ORDAINED that this Ordinance be in full force and effect from and after its passage by the Common Council, signing by the Mayor and appropriate public notice in a newspaper of general circulation.

PASSED AND ADOPTED by the Common Council of the City of Auburn, Indiana, this _________ day of ______________________, 2006.

____
RICHARD CRAWFORD
Councilmember

ATTEST:

____
Patricia M. Miller
Clerk-Treasurer

Presented by me to the Mayor of the City of Auburn, Indiana, this _____ day of _____________, 2006.

____
PATRICIA M. MILLER
Clerk-Treasurer

O:\Auburn - City of\I061552\H - Reports & Plans\H2 Final Reports or Plans (Submitted to Others)\Ordinances\05. Ordinance for Stormwater Construction Site.doc

1[st] Reading____________
2[nd] Reading____________

APPROVED AND SIGNED by me this ____ day of ________________________, 2006.

____
NORMAN E. YODER, Mayor

VOTING:	**AYE**	**NAY**
Richard S. Ring		
Marilyn Gearhart		
David Painter		
James Finchum		
Greg Kenner		
Richard Crawford		
Michael Walter		

1st Reading__________
2nd Reading__________

CHAPTER 161.000
CONSTRUCTION SITE
STORM WATER RUNOFF CONTROL.

Table of Contents

161.001 Introduction/ Purpose

During the construction process, soil is highly vulnerable to erosion by wind and water. Eroded soil endangers water resources by reducing water quality and causing the siltation of aquatic habitat for fish and other desirable species. Eroded soil also necessitates repair of sewers and ditches and the dredging of lakes. In addition, clearing and grading during construction cause the loss of native vegetation necessary for terrestrial and aquatic habitat.

As a result, the purpose of this local regulation is to safeguard persons, protect property, and prevent damage to the environment and the City of Auburn. This ordinance will also promote the public welfare by guiding, regulating, and controlling the design, construction, use, and maintenance of any development or other activity that disturbs or breaks the topsoil or results in the movement of earth on land in the City of Auburn.

161.002 Definitions

<u>Agricultural Conservation Practices</u> means practices that are constructed on agricultural land for the purposes of controlling soil erosion and sedimentation. These practices include grass waterways, sediment basins, terraces, and grade stabilization structures.

<u>Agricultural Land Disturbing Activity</u> means tillage, planting, cultivation, or harvesting operations for the production of agricultural or nursery vegetative crops. The term also includes pasture renovation and establishment, the construction of agricultural conservation practices, and the installation and maintenance of agricultural drainage tile. For purposes of this ordinance, the term does not include land disturbing activities for the construction of agricultural related facilities, such as:

(A) barns;

(B) buildings to house livestock;

(C) roads associated with infrastructure;

(D) agricultural waste lagoons and facilities;

(E) lakes and ponds;

(F) wetlands; and

(G) other infrastructure.

<u>Best Management Practices (BMPs)</u> – means structural or nonstructural practices, or a combination of practices, designed to act as effective, practicable means of minimizing the impacts of development and human activities on

water quality. Traditional structural BMPs, including extended detention dry ponds, wet ponds, infiltration trenches, and sand filtration systems are now common elements of most new development projects. Structural BMPs rely heavily on gravitational settling and/or the infiltration of soluble nutrients though a porous medium for pollutant removal. Nonstructural BMPs, which may be used independently or in conjunction with structural BMPs, rely on a much wider breadth of mechanisms to prevent or control non point source pollution (NPS). Nonstructural BMPs range from programs that increase public awareness to prevent pollution, to the implementation of control-oriented techniques (such as bioretention and storm water wetlands) that utilize vegetation to enhance pollutant removal and restore the infiltrative capacity of the landscape.

Certified Contractor - means a person who has received training related to the Indiana Department of Environmental Management Rule 5 and Rule 13 procedures to inspect and maintain erosion and sediment control practices.

City of Auburn – means employees or designees of the City of Auburn designated to enforce and administer this ordinance.

Clearing – means any activity that removes the vegetative surface cover.

Construction Activity - means land disturbing activities and land disturbing activities associated with the construction of infrastructure and structures. This term does not include routine ditch or road maintenance or minor landscaping projects.

Construction Plan – means a representation of a project site and all activities associated with the project. The plan includes the location of the project site, buildings and other infrastructure, grading activities, schedules for implementation, and other pertinent information related to the project site. A storm water pollution prevention plan is a part of the construction plan.

Construction site access – means a stabilized stone surface at all points of ingress or egress to a project site for the purpose of capturing and detaining sediment carried by tires of vehicles or other equipment entering or exiting the project site.

Contractor or Subcontractor - means an individual or company hired by the project site or individual lot owner, their agent, or the individual lot operator to perform services on the project site.

Developer - means (A) any person financially responsible for construction activity; or (B) an owner of property who sells or leases, or offers for sale or lease, any lots in a subdivision.

Discharge of a Pollutant – means any addition of any pollutant, or combination of pollutants, into any waters of the state from a point source in Indiana. The term includes, without limitation, additions of pollutants into waters of the state from the following: (1) Surface run-off collected or channeled by man. (2) Discharges through pipes, sewers, or other conveyances that do not lead to treatment works.

Drainage Way- means any channel that conveys surface runoff throughout the site.

Erosion - means the detachment and movement of soil, sediment, or rock fragments by water, wind, ice, or gravity.

Erosion and Sediment Control Measure - means a practice or a combination of practices, to control erosion and resulting sedimentation.

Erosion and Sediment Control System - means the use of appropriate erosion and sediment control measures to minimize sedimentation by first reducing or eliminating erosion at the source and then, as necessary, trapping sediment to prevent it from being discharged from or within a project site.

Final Stabilization - means the establishment of permanent vegetative cover or the application of a permanent non-erosive material to areas where all land disturbing activities have been completed and no additional land disturbing activities are planned under the current permit.

Grading - means the cutting and filling of the land surface to a desired slope or elevation.

Impervious Surface - means surfaces, such as pavement and rooftops that prevent the infiltration of storm water into the soil.

Individual Lot - means a single parcel of land within a multi-parcel development.

Individual Lot Operator - means a contractor or subcontractor working on an individual lot.

Individual Lot Owner - means a person who has financial control of construction activities for an individual lot.

Land Disturbing Activity - means any manmade change of the land surface, including removing vegetative cover that exposes the underlying soil, excavating, filling, transporting, and grading. This term does not include routine ditch or road maintenance or minor landscaping projects.

Larger Common Plan of Development or Sale - means a plan, undertaken by a single project site owner or a group of project site owners acting in concert, to offer lots for sale or lease; where such land is contiguous, or is known, designated, purchased or advertised as a common unit or by a common name, such land shall be presumed as being offered for sale or lease as part of a larger common plan. The term also includes phased or other construction activity by a single entity for its own use.

Measurable Storm Event - means a precipitation event that results in a total measured precipitation accumulation equal to, or greater than, one-half (0.5) inch of rainfall.

MS4 Area - means the land area described in the City of Auburn MS4 general storm water permit pursuant to 327 IAC 15-13.

MS4 Operator - means the person responsible for development, implementation, or enforcement of the minimum control measures for the City of Auburn MS4 area.

Municipal Separate Storm Sewer System" or "MS4" - means a conveyance or system of conveyances, including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels, or storm drains, that is:

(A) Owned or operated by a:

(i) federal, state, city, town, county, district, association, or other public body (created by or pursuant to state law) having jurisdiction over storm water, including special districts under state law such as a sewer district, flood control district or drainage district, or similar entity, or a designated and approved management agency under Section 208 of the Clean Water Act (33 U.S.C. 1288) that discharges into waters of the state; or

(ii)

(ii) Privately owned storm water utility, hospital, university or college having jurisdiction over storm water that discharges into waters of the state;

(B) Designed or used for collecting or conveying storm water;

(C) Not a combined sewer; and

(D) Not part of a publicly owned treatment works (POTW).

Peak Discharge - means the maximum rate of flow during a storm, usually in reference to a specific design storm event.

Permanent Stabilization - means the establishment, at a uniform density of seventy percent (70%) across the disturbed area, of vegetative cover or permanent non-erosive material that will ensure the resistance of the soil to erosion, sliding, or other movement.

Pollutant – means anything that causes or contributes to pollution discharged into waterways. Pollutants may include, but are not limited to: paints, varnishes, and solvents; oil and other automotive fluids; non-hazardous liquid and solid wastes and yard wastes; refuse, rubbish, garbage, litter, or other discarded or abandoned objects, and accumulations, so that the same may cause or contribute to pollution; floatables; pesticides, herbicides, and fertilizers; hazardous substances and wastes; sewage, fecal coliform and pathogens; dissolved and particulate metals; animal wastes; wastes and residues that result from constructing a building or structure; and noxious or offensive matter of any kind. Also, but not limited to dredged spoil; incinerator residue, filter backwash; sewage; garbage; sludge; munitions; chemical wastes; solid wastes; toxic wastes; hazardous substances; biological materials; radioactive materials (except those regulated under the Atomic Energy Act of 1954, as amended; 42 U.S.C. 011, et seq., heat, wrecked or discarded equipment; rock; sand; cellar dirt; and other industrial, municipal, and agricultural waste; discharged into water.

Phasing of Construction - means sequential development of smaller portions of a large project site, stabilizing each portion before beginning land disturbance on subsequent portions, to minimize exposure of disturbed land to erosion.

Project Site - means the entire area on which construction activity is to be performed.

Project Site Owner - means the person required to submit the Erosion Control Permit Application under this ordinance and required to comply with the terms of this ordinance, including either of the following:

(A) A developer.

(B) A person who has financial and operational control of construction activities and project plans and specifications, including the ability to make modifications to those plans and specifications.

Publicly Owned Treatment Works" or (POTW) - means a treatment works as defined by Section 212 of the Act, (33 U.S.C. 1292) owned in this instance by the City of Auburn. This definition includes any sewers, pipes, and other conveyances conveying wastewater to the POTW treatment plant. The term does not include pipes, sewers or other conveyances not connected to a facility providing treatment or storage. For the purposes of this Ordinance, "POTW" shall also include any sewers, pipes or other conveyances that convey wastewaters to the POTW from persons outside the City who are, by contract or agreement with the City, users of the City's POTW. The term also means the municipality, as defined in Section 502(4) of the Clean Water Act, which has jurisdiction over the discharges to and the direct discharges from such a treatment works.

Runoff - means waters derived from melting snow or rain falling within a tributary drainage basin that exceed the infiltration capacity of the soils of that basin, flow over the surface of the ground, or are collected in channels or conduits.

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.

Sedimentation - means the settling and accumulation of unconsolidated sediment carried by storm water run-off.

Soil - means the unconsolidated mineral and organic material on the surface of the earth that serves as the natural medium for the growth of plants.

Soil and Water Conservation District (SWCD) - means the DeKalb County Soil and Water Conservation District.

Storm Water Pollution Prevention Plan (SWPP) - means a plan developed to minimize the impact of storm water pollutants resulting from land disturbing activities. The plan includes the location of the project site, buildings and other infrastructure, grading activities, schedules for implementation, and other pertinent information related to the control of storm water pollutants.

Storm Water Quality Measure - means a practice, or a combination of practices, to control or minimize pollutants associated with storm water run-off.

Strip Development - means a multi-lot project site where individual lots front on an existing road.

Subdivision - means any land that is divided or proposed to be divided into lots, whether contiguous or subject to zoning requirements, for the purpose of sale or lease as part of a larger common plan of development or sale.

Temporary Stabilization - means the covering of soil to ensure its resistance to erosion, sliding, or other movement. The term includes vegetative cover, anchored mulch, or other non-erosive material applied at a uniform density of seventy percent (70%) across the disturbed area.

Tracking - means the deposition of soil that is transported from one (1) location to another by tires, tracks of vehicles, or other equipment.

Trained Individual - means an individual who is trained and experienced in the principles of storm water quality, including erosion and sediment control as may be demonstrated by state registration, professional certification, experience, or completion of coursework that enable the individual to make judgments regarding storm water control or treatment and monitoring.

161.003 Applicability

The requirements under this ordinance are in compliance with 327 IAC 15-5 (Rule 5) and apply to all persons meeting the requirements of IAC 15-5-2. This ordinance requires the control of polluted run-off from construction sites with a land disturbance greater than or equal to one acre or disturbances of less than one acre if it is part of a larger common plan of development or sale that will disturb more than one acre as determined below.

(1) For off-site construction activities that provide services including, but not limited to, road extensions, sewer, water, and other utilities, to a permitted project site, these off-site activity areas must be considered a part of the permitted project site when the activity is under the control of the project site owner.

(2) Multi-lot project sites are regulated by this ordinance in accordance with the following, unless the total combined land disturbance on all individual lots is less than one (1) acre and is not part of a larger common plan of development or sale:

(1) A determination of the area of land disturbance shall be calculated by adding the total area of land disturbance for improvements, such as roads, utilities, or common areas, and the expected total disturbance on each individual lot, as determined by the following:

(A) For a single-family residential project site where the lots are one-half (0.5) acre or more, one-half (0.5) acre of land disturbance must be used as the expected lot disturbance.

(B) For a single-family residential project site where the lots are less than one-half (0.5) acre in size, the total lot must be calculated as being disturbed.

(C) To calculate lot disturbance on all other types of project sites, such as industrial and commercial project sites, the following apply:

(i) Where lots are one (1) acre or greater in size, a minimum of one (1) acre of land disturbance must be calculated as the expected lot disturbance.

(ii) Where the lots are less than one (1) acre in size, the total lot must be calculated as being disturbed.

(3) For purposes of this ordinance, strip developments:

(A) Are considered as one (1) project site; and

(B) Must comply with this ordinance.

(4) The requirements under this rule do not apply to persons who are

involved in agricultural land disturbing activities or forest harvesting activities.

(5) The requirements under this rule do not apply to the following activities, provided other applicable permits contain provisions requiring immediate implementation of soil erosion control measures.

a. Landfills that have been issued a certification of closure under 329 IAC 10

b. Coal mining activities permitted under IC 14-34

c. Municipal solid waste landfills that are accepting waste pursuant to a permit issued by the Indiana Department of Environmental Management (IDEM) under 329 IAC 10 that contains equivalent storm water requirements, including the expansion of landfill boundaries and construction of new cell either within or outside the original solid waste permit boundary

d. Road and regulated drain maintenance

161.004 Project Site Owner Responsibilities

(a) The project site owner has the following responsibilities:

(1) Ensure that a Storm Water Pollution Prevention Plan (SWPPP) is completed and submitted in accordance with Section 8 of this ordinance.

(2) Ensure compliance with this ordinance during the land disturbing activity and the implementation of the SWPPP.

(3) Complete and submit a Notice of Intent (NOI) in accordance with Section 7 of this ordinance.

(4) Complete and submit a notice of termination letter (NOT) in accordance with Section 11 of this ordinance.

(5) Ensure that all persons engaging in construction activities on a permitted project site comply with the applicable requirements of this ordinance and the approved SWPPP.

(6) The project site owner shall inform all general contractors, construction management firms, grading or excavating contractors, utility contractors, and the contractors that have primary oversight on individual building lots of the requirements of this ordinance, the conditions and standards included in the SWPPP and the schedule for proposed implementation.

161.005 Individual Lot Owner or Operator Responsibilities

(a) An Individual Lot Operator, whether owning the property or acting as the agent of the property owner, shall be responsible for erosion and sediment control requirements associated with the activities on Individual Lots.

(b) For an Individual Lot where land disturbance is expected to be one (1) acre or more and the lot lies within a project site permitted under this ordinance, the Individual Lot Owner shall:

(1) Complete and submit a Notice of Intent (NOI) in accordance with Section 7 of this ordinance; and

(2) Ensure that a SWPPP is completed and submitted in accordance with Section 8 of this ordinance.

(c) For an Individual Lot where the land disturbance is less than one (1) acre and the lot lies within a project site permitted under this ordinance, the Individual Lot Operator is not required to submit an Erosion Control Permit Application or a SWPPP. The individual lot operator shall comply with the provisions and requirements of the SWPPP developed by the project site owner and the requirements under Section 6 of this ordinance.

161.006 General Requirements for Storm Water Pollution Prevention

(a) The following requirements shall be met on all project sites:

(1) Sediment-laden water flowing from the project site shall be treated by erosion and sediment control measures appropriate to minimize sedimentation.

(2) Appropriate measures shall be implemented to minimize or eliminate wastes or unused building materials, including garbage, debris, cleaning wastes, wastewater, concrete truck washout, and other substances from being carried from a project site by run-off or wind. Identification of areas where concrete truck washout is permissible must be clearly posted at appropriate areas of the site. Wastes and unused building materials shall be managed and disposed of in accordance with all applicable statutes and regulations.

(3) A stable construction site access shall be provided at all points of construction traffic ingress and egress to the project site.

(4) Public or private roadways shall be kept cleared of accumulated sediment that is a result of run-off or tracking. Bulk clearing of sediment shall not include flushing the area with water. Cleared sediment shall be redistributed or disposed of in a manner that is in accordance with all applicable statutes and regulations.

(5) Storm water run-off leaving a project site must be discharged in a manner that is consistent with applicable state or federal law.

(6) Phasing of construction activities shall be used, where possible, to minimize disturbance of large areas.

(7) Appropriate measures shall be planned and installed as part of an erosion and sediment control system.

(8) All storm water quality measures must be designed and installed under the guidance of a trained individual.

(9) Collected run-off leaving a project site must be either discharged directly into a well-defined, stable receiving channel or diffused and released to adjacent property without causing an erosion or pollutant problem to the adjacent property owner.

(10) Drainage channels and swales must be designed and adequately protected so that their final gradients and resultant velocities will not cause erosion in the receiving channel or at the outlet.

(11) Natural features, including wetlands and sinkholes, shall be protected from pollutants associated with storm water run-off.

(12) Unvegetated areas that are scheduled or likely to be left inactive for fifteen (15) calendar days or more must be temporarily or permanently stabilized with measures appropriate for the season to minimize erosion potential. Alternative measures to site stabilization are acceptable if the project site owner or their representative can demonstrate they have implemented erosion and sediment control measures adequate to prevent sediment discharge. Vegetated areas with a density of less than seventy percent (70%) shall be restabilized using appropriate methods to minimize the erosion potential.

(13) During the period of construction activities, all storm water quality measures necessary to meet the requirements of this rule shall be maintained in working order.

(19) Proper storage and handling of materials, such as fuels or hazardous wastes, and spill prevention and clean-up measures shall be implemented to minimize the potential for pollutants to contaminate surface or ground water or degrade soil quality.

(20) Final stabilization of a project site is achieved when:

(A) all land disturbing activities have been completed and a uniform (for example, evenly distributed, without large bare areas) perennial vegetative cover with a density of seventy percent (70%) has been established on all unpaved areas and areas not covered by permanent structures, or equivalent permanent stabilization measures have been employed; and

(B) construction projects on land used for agricultural purposes are returned to its preconstruction agricultural use or disturbed areas, not previously used for agricultural production, such as filter strips and areas that are not being returned to their preconstruction agricultural use, meet the final stabilization requirements in subsection (A);

(C) for individual residential lots, final stabilization meeting the criteria in subsection (A) will be achieved when the individual lot operator:

(A) completes final stabilization; or

(B) has installed appropriate erosion and sediment control measures for an individual lot prior to occupation of the home by the homeowner and has informed the homeowner of the requirement for, and benefits of, final stabilization.

161.007 Notice of Intent

a. **Information Requirements**

The project site owner must submit the following information with a complete NOI letter under this ordinance:

(1) Name, mailing address, and location of the project site for which the notification is submitted.

(2) The project site owner's name, address, telephone number, e-mail address (if available), ownership status as federal, state, public, private, or other entity.

(3) Contact person (if different than project site owner), person's name, company name, address, e-mail address (if available), and telephone number.

(4) A brief description of the construction project, including a statement of the total acreage of the project site. Total acreage claimed in the NOI letter shall be consistent with the acreage covered in the construction plan.

(5) Estimated dates for initiation and completion of construction activities. Within forty-eight (48) hours of the initiation of construction activity, the project site owner must notify the commissioner and the appropriate plan reviewing agency of the actual project start date.

(6) The latitude and longitude of the approximate center of the project site to the nearest fifteen (15) seconds, and the nearest quarter section, township, range, and civil township in which the project site is located.

(7) Total impervious surface area, in square feet, of the final project site including structures, roads, parking lots, and other similar improvements.

(8) The number of acres to be involved in the construction activities.

(9) Proof of publication in a newspaper of general circulation in the affected area that notified the public that a construction activity is to commence, that states, "(Company name, address) is submitting an NOI letter to notify the City of Auburn MS4 and the Indiana Department of Environmental Management of our intent to comply with the requirements under 327 IAC 15-5 to discharge storm water from construction activities for the following project: (name of the construction project, address of the location of the construction project). Run-off from the project site will discharge to (stream(s) receiving the discharge(s))."

(10) As applicable, a list of all MS4 areas designated under 327 IAC 15-13 within which the project site lies.

(11) A written certification by the operator that:

(A) the storm water quality measures included in the construction plan comply with the requirements of this ordinance;

(B) the measures required by section 6 of this rule will be implemented in accordance with the storm water pollution prevention plan;

(C) if the projected land disturbance is one (1) acre or more, the applicable soil and water conservation district or other entity designated by the department has been sent a copy of the construction plan for review;

(D) storm water quality measures beyond those specified in the storm water pollution prevention plan will be implemented during the life of the permit if necessary to comply with section 6 of this rule; and

(E) implementation of storm water quality measures will be inspected by trained individuals.

(12) The name of receiving water or, if the discharge is to a municipal separate storm sewer, the name of the municipal operator of the storm sewer and the ultimate receiving water.

(13) The NOI letter must be signed by a person meeting the signatory requirements in 327 IAC 15-4-3(g).

(14) A notification from the DeKalb County SWCD or an authorized IDEM representative or the City of Auburn MS4 indicating that the constructions plans are sufficient to comply with this rule. This requirement may be waived if the project site owner has not received notification from the reviewing agency within 28 days.

(A) Send NOI letters to:
Attention: Rule 5 Storm Water Coordinator
Indiana Department of Environmental Management
Office of Water Quality, Urban Wet Weather Section
100 North Senate Avenue
P.O. 6015
Indianapolis, Indiana 46206-6015
AND
MS4 Operator
City of Auburn
2010 South Wayne Street
Auburn, Indian 46706

DeKalb County SWCD
942 W 15th Street
Auburn, Indiana 46706

b. Submission Requirements

After the project site owner has received notification from the reviewing agency that the construction plans meet the requirements of the rule or the 28 day review period has expired, all NOI letter information required under Section 7(a) of this rule shall be submitted to the commissioner at least forty-eight (48) hours prior to the initiation of land disturbing activities at the site. If the NOI letter is determined to be deficient, the project site owner must address the deficient items and submit an amended NOI letter to all parties as specified in Section 7(a) of this ordinance.
For a project site where the proposed land disturbance is one (1) acre or more as determined under section 3 of this rule, the following requirements must be met:

(1) A construction plan must be submitted according to the following:

(A) Prior to the initiation of any land disturbing activities.

(B) Sent to the DeKalb County SWCD or IDEM authorized representative or the City of Auburn for review and verification that the plan meets the requirements of the rule

(2) If the construction plan required by subdivision (1) is determined to be deficient, the DeKalb County SWCD or IDEM or IDEM authorized representative or the City of Auburn may require modifications, terms, and conditions as necessary to meet the requirements of the rule. The initiation of construction activity following notification by the reviewing agency that the plan does not meet the requirements of the rule is a violation and subject to enforcement action. If notification of a deficient plan is received after the review period outlined in subdivision (3) and following commencement of construction activities, the plans must be modified to meet the requirements of the rule and resubmitted within fourteen (14) days of receipt of the notification of deficient plans.

(3) If the project site owner does not receive notification within twenty-right (28) days after the plan is received by the reviewing agency stating that the reviewing agency finds the plan is deficient, the project site owner may submit the NOI letter information.

161.008 Storm Water Pollution Prevention Plan

a. Submission Requirements

For a project site where the proposed land disturbance is one (1) acre or more as determined under Section 3 of this ordinance, the following requirements must be met:

(1) A Storm Water Pollution Prevention Plan (SWPPP) containing the information required in Section 8(b) of this ordinance must be submitted to the DeKalb County SWCD or an IDEM authorized representative prior to the initiation of any land disturbing activities.

Submit two copies of the SWPPP to:
DeKalb County SWCD
942 W 15th Street

Auburn, Indiana 46706

(2) The DeKalb County SWCD or an IDEM authorized representative will review each application for a site development permit to determine its conformance with the provisions of this regulation. Within 28 days after receiving an application the DeKalb County SWCD or an IDEM authorized representative shall, in writing:

1 Approve the permit application;

2 Approve the permit application subject to such reasonable conditions as may be necessary to secure substantially the objectives of this regulation, and issue the permit subject to these conditions; or

3 Disapprove the permit application, indicating the reason(s) and procedure for submitting a revised application and/or submission.

(3) Failure of the DeKalb County SWCD or an IDEM authorized representative to act on an original or revised application within 28 days of receipt shall authorize the applicant to proceed in accordance with the plans as filed unless such time is extended by agreement between the applicant and the DeKalb County SWCD or an IDEM authorized representative. Pending preparation and approval of a revised plan, development activities shall be allowed to proceed in accordance with conditions established by the DeKalb County SWCD or an IDEM authorized representative.

(4) Approval of construction plans shall be based on Rule 5 regulations and any design criteria in the City of Auburn Storm Water BMP manual.

(5) If construction plans are altered after approval then they must be resubmitted for additional review.

(6) If the SWPPP required by subdivision (1) is determined to be deficient, the SWCD may require modifications, terms, and conditions as necessary to meet the requirements of this ordinance. A notice of deficiency will be sent and permit will not be issued. Deficient items will need to be amended and resubmitted and will begin a 14-28-day review period. The initiation of land disturbing activities following written notification by the SWCD or an authorized IDEM representative or the City of Auburn that the SWPPP does not meet the requirements of this ordinance is a violation of this ordinance and subject to enforcement action.

b. Information Requirements

A project site owner shall develop a Storm Water Pollution Prevention Plan designed to achieve the storm water quality and erosion control requirements specified in Section 6 of this ordinance. The SWPPP shall serve as a guideline for storm water quality, but should not be interpreted to be the only basis for implementation of storm water quality measures for a project site. The project site owner is responsible for implementing, in accordance with this rule, all measures necessary to adequately prevent polluted storm water run-off. The SWPPP must include the following:

(1) Project narrative and supporting documents, including the following information:

(A) An index indicating the location, in the plan, of all information required by this subsection.

(B) Description of the nature and purpose of the project.

(C) Legal description of the project site. The description should be to the nearest quarter section, township, and range, and include the civil township.

(D) Soil properties, characteristics, limitations, and hazards associated with the project site and the measures that will be integrated into the project to overcome or minimize adverse soil conditions.

(E) General construction sequence of how the project site will be built, including phases of construction.

(F) Identify the name and the Hydrologic Unit Code (14 Digit) available from the United States Geological Survey (USGS) for the watershed the project is located in.

(G) A reduced plat or project site map showing the applicable lot numbers, lot boundaries, and road layout and names. The reduced map must be legible and submitted on a sheet or sheets no larger than eleven (11) inches by seventeen (17) inches for all phases or sections of the project site.

(H) Identification of any other state or federal water quality permits that are required for construction activities associated with the owner's project site.

(2) Vicinity map depicting the project site location in relationship to recognizable local landmarks, towns, and major roads, such as a USGS topographic quadrangle map or county or municipal road map.

(3) A project site layout that must include the following information:

(A) Location and name of all wetlands, lakes, and watercourses on or adjacent to the project site.

(B) Location of all existing structures on the project site, if applicable.

(C) One hundred (100) year floodplains, floodway fringes, and floodways. Please note if none exists.

(D) Soil map of the predominant soil types, as determined by the United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) Soil Survey, or an equivalent publication, or as determined by a soil scientist. A soil legend must be included with the soil map.

(E) Identification and delineation of vegetative cover, such as grass, weeds, brush, and trees, on the project site.

(F) Land use of all adjacent properties.

(G) Existing topography at a contour interval appropriate to indicate drainage patterns.

(H) Location of all proposed site improvements, including roads, utilities, lot delineation and identification, proposed structures, and common areas.

(4) A construction grading plan, including the following information:

(A) Delineation of all proposed land disturbing activities, including off-site activities that will provide services to the project site.

(B) Location of all soil stockpiles and borrow areas.

(C) Information regarding any off-site borrow, stockpile, or disposal areas that are associated with a project site and under the control of the project site owner.

(D) Proposed final topography at a contour interval appropriate to indicate drainage patterns.

(E) Proposed final one hundred (100) year floodplains, floodway fringes, and floodways, if different than existing.

(5) A Stormwater Pollution Prevention Plan, including the following

information:

(A) An estimate of the peak discharge, based on the ten (10) year storm event, of the project site for both preconstruction and post construction conditions

(B) Location, size, and dimensions of all storm water management systems, such as culverts, storm sewers, conveyance channels, permanent retention or detention facilities, including existing or manmade wetlands.

(C) Locations where storm water may be directly discharged into ground water, such as abandoned wells or sinkholes. Please note if none exists.

(D) Locations of specific points where storm water discharge will leave the project site.

(E) Name of all receiving waters. If the discharge is to a separate municipal storm sewer, identify the name of the municipal operator and the ultimate receiving water.

(F) Location, dimensions, detailed specifications, and construction details of all temporary and permanent storm water quality measures.

(G) Temporary and permanent stabilization plans include sequence of implementation and the following:

(i) Specifications and application rates for soil amendments and seed mixtures.

(ii) The type and application rate for anchored mulch.

(H) Construction sequence describing the relationship between implementation of storm water quality measures and stages of construction activities.

(I) Self-monitoring program including plan and procedures.

(J) A description of potential pollutant sources associated with the construction activities that may reasonably be expected to add a significant amount of pollutants to storm water discharges.

(K) Material handling and storage associated with the construction activity shall meet the storage, spill prevention and spill response requirements in the City of Auburn Ground Water Protection Ordinance, as amended.

(6) A copy of the post construction storm water management plan.

(b) The MS4 Operator or the SWCD or an IDEM authorized representative may upon finding reasonable cause require modification to the SWPPP if it is determined that changes are necessary due to site conditions or project design changes. Revised plans, if requested, must be submitted to the appropriate entity within twenty-eight (28) calendar days of a request for a modification or before land disturbance.

161.009 Self-Monitoring Requirements

(a) A self-monitoring program that includes the following must be implemented at all permitted project sites:

(1) A trained individual shall perform a written evaluation of the project site:

(A) by the end of the next business day following each measurable storm event; and

(B) at a minimum of one (1) time per week.

(2) The evaluation must:

(A) address the maintenance of existing storm water quality measures to ensure they are functioning properly; and

(B) identify additional measures necessary to remain in compliance with all applicable statutes and rules.

(3) Written evaluation reports must include:

(A) the name of the individual performing the evaluation;

(B) the date of the evaluation;

(C) problems identified at the project site; and

(D) details of corrective actions recommended and completed.

(4) All evaluation reports for the project site must be made available to the MS4 Operator or other designated entity within forty-eight (48) hours of a request.

(5) Maintain inspection records for three (3) from date of NOT.

161.010 Inspection and Violations

(a) DeKalb County SWCD, IDEM, or an IDEM authorized representative shall make inspections as hereinafter required and either approve that portion of the work completed or shall notify the permittee wherein the work fails to comply with the SWPP as approved. Plans for grading, stripping, excavating, and filling work bearing the stamp of approval of the DeKalb County SWCD, IDEM, or an IDEM or an IDEM authorized representative shall be maintained at the site during the progress of the work. To obtain inspections, the permittee shall notify the DeKalb County SWCD, IDEM, or an IDEM authorized representative at least two working days before the following:

a. Start of construction

b. erosion control measures

c. Completion of site clearing

d. Completion of rough grading

e. Completion of final grading

f. Close of the construction season

g. Completion of final landscaping

(b) The DeKalb County SWCD, IDEM, or an IDEM, or an IDEM authorized representative shall enter the property of the applicant as deemed necessary to make regular inspections to ensure the validity of the reports filed under Section 9.

(c) All persons engaging in construction activities on a project site shall be responsible for complying with the SWPPP and the provisions of this ordinance.

(d) The MS4 Operator or an IDEM authorized representative shall investigate potential violations of this ordinance to determine which person may be responsible for the violation. The MS4 Operator or an IDEM authorized representative shall, if appropriate, consider public records of ownership, building permits issued by local units of government, and other relevant information, which may include site inspections, storm water pollution prevention plans, permit applications, and other information related to the specific facts and circumstances of the potential violation. Any person causing or contributing to a violation of any provisions of this ordinance shall be subject to enforcement and penalty under section 13.

161.011 Project Termination

(a) The project site owner shall plan an orderly and timely termination of the land disturbing activities, including the implementation of storm water quality measures that are to remain on the project site.

(b) Except as provided in subdivision (c), the project site owner shall submit a Notice of Termination (NOT) letter to the MS4 Operator or other designated entity certifying that each of the following conditions have been met:

(1) All land disturbing activities, including construction on all building lots, have been completed and the entire site has been stabilized.

(2) All temporary erosion and sediment control measures have been removed.

(3) All post-construction certified BMPs and associated control devices have been installed and documented with jurisdictional entity.

(c) The project site owner may submit an NOT letter to obtain early release from compliance with this ordinance if the following conditions are met:

(A) The remaining, undeveloped acreage does not exceed five (5) acres, with contiguous areas not to exceed one (1) acre.
(B) A map of the project site, clearly identifying all remaining undeveloped lots, is attached to the NOT letter. The map must be accompanied by a list of names and addresses of individual lot owners or individual lot operators of all undeveloped lots.

(C) All public and common improvements, including infrastructure, have been completed and permanently stabilized and have been transferred to the appropriate local entity.

(D) The remaining acreage does not pose a significant threat to the integrity of the infrastructure, adjacent properties, or water quality.

(E) All permanent storm water quality measures have been implemented and are operational.

(d) The MS4 Operator or other designated entity shall verify the information in the NOT letter. Upon receipt of written approval of the NOT letter from the MS4 Operator or other designated entity, the Erosion Control Permit shall no longer be valid and the project site owner shall no longer be responsible for compliance with this ordinance.

(e) Following receipt of a written approval of an early release NOT letter in accordance with Subsection (c), the project site owner shall notify all current individual lot owners and all subsequent individual lot owners of the remaining undeveloped acreage and acreage with construction activity that they are responsible for complying with under Section 6 of this ordinance. The remaining individual lot owners do not need to submit an SWPPP or an NOT letter. The notice must contain a verified statement that each of the conditions in subsection (c) have been met. The notice must also inform the individual lot owners of the requirements to:

(1) install and maintain appropriate measures to prevent sediment from leaving the individual building lot; and

(2) maintain all erosion and sediment control measures that are to remain on-site as part of the construction plan.

(f) After a verified NOT letter has been submitted for a project site, maintenance of the remaining storm water quality measures shall be the responsibility of the individual lot owner or occupier of the property

161.012 Duration of Permit

(a) A permit issued under this ordinance is granted for a period of five (5) years from the date coverage commences.

(b) Once the five (5) year permit term duration is reached, the permit issued under this ordinance will be considered expired, and, as necessary for construction activity continuation, a new permit application would need to be submitted in accordance with subsection (c).

(c) To obtain a renewal permit, the information required under Section 7 of this ordinance must be submitted to the MS4 Operator ninety (90) calendar days prior to the termination date of the permit. Coverage under a renewal permit will begin on the date of expiration from the previous five (5) year permit term. SWPPP should be updated if necessary.

161.013 Enforcement

(a) Stop-Work Order; Revocation of Permit
In the event that any person holding a site development permit pursuant to this ordinance violates the terms of the permit or implements site development in such a manner as to materially adversely affect the health, welfare, or safety of persons residing or working in the neighborhood or development site so as to be materially detrimental to the public welfare or injurious to property or improvements in the neighborhood, the City of Auburn or its designated representatives may refer the matter to IDEM for enforcement.

(b) If remaining storm water quality measures are not properly maintained by the person occupying or owning the property, IDEM may pursue enforcement against that person for correction of deficiencies under 327 IAC 15-1-4.

(c) Construction plans, SWPPP, self-inspection logs, and other supporting documentation associated with the project site must be made available to the MS4 Operator or its designated representatives within forty-eight (48) hours of such a request.

(d) Violation and Penalties
No person shall construct, enlarge, alter, repair, or maintain any grading, excavation, or fill, or cause the same to be done, contrary to or in violation of any terms of this ordinance. Any penalties for violation of this ordinance shall be governed by IC 13-18-4 as detailed in 327 IAC 15-1 et al.

161.014 Separability

The provisions and sections of this ordinance shall be deemed to be separable, and the invalidity of any portion of this ordinance shall not affect the validity of the remainder.

1st Reading 7/18/06
2nd Reading 8/1/06

Received 7/11/06
Clerk-Treasurer's Office
Auburn Indiana

ORDINANCE NO. 2006-10

AN ORDINANCE TO ESTABLISH RULES RELATED TO POST CONSTRUCTION STORM WATER CONTROL

SUMMARY

The purpose of this ordinance is to provide for the health, safety, and general welfare of the citizens of the City of Auburn through the regulation of non-storm water discharges to the municipal separate storm sewer (MS4) conveyance system to the maximum extent practicable as required by federal and state law.

____	Recorder's Office	7/20/06	Publish Public Hearing
____	Auditor's Office	8/1/06	
x	Clerk's Office	x	Publish O/R after adoption
____	Other		
x	Internet Web Based City Code		

1st Reading____________
2nd Reading____________

ORDINANCE NO. 2006-10

AN ORDINANCE TO ESTABLISH RULES RELATED TO POST CONSTRUCTION STORM WATER CONTROL

BE IT ORDAINED BY THE COMMON COUNCIL OF THE CITY OF AUBURN, INDIANA:

Section I

That the following attached Exhibit "A" shall be adopted as an Ordinance of the Municipal City of Auburn, Indiana, codified, and placed on the City of Auburn, Indiana internet web-based municipal code site.

The ordinance shall be codified as Chapter 162 of the Auburn Municipal Code and placed on the internet web-based site as set forth in Exhibit "A" (codified form).

The Clerk-Treasurer shall cause this ordinance to be published in the Evening Star Newspaper upon its passage. A public hearing regarding this Ordinance shall take place before its second reading. An original copy of this Ordinance shall be maintained by the Clerk-Treasurer.

Section II

BE IT FURTHER ORDAINED that this Ordinance shall be in full force and effect from and after its passage by the Common Council and signing by the Mayor and proper publication in a newspaper of general circulation.

PASSED AND ADOPTED by the Common Council of the City of Auburn, Indiana, this __1__ day of __August________, 2006.

James Finchum

James Finchum, Councilmember

1st Reading____________
2nd Reading____________

ATTEST:

Patricia Miller
Clerk-Treasurer

Presented by me to the Mayor of the City of Auburn, Indiana, this __1st___ day of ______August__________, 2006.

PATRICIA MILLER
Clerk-Treasurer

APPROVED AND SIGNED by me this __1st___ day of _______August__________, 2006.

NORMAN E. YODER, Mayor

VOTING:	**AYE**	**NAY**
Richard S. Ring		
David Painter		
James Finchum		
Marilyn Gearhart		
Stan Greenlee		
Greg Kenner		
Michael Walter		

1st Reading____________
2nd Reading____________

Exhibit
"A"

(Codify as follows)

CHAPTER 162 Post Construction Storm Water Control

Table of Contents

1st Reading______________
2nd Reading______________

Section 162.001
Introduction/Purpose

Purpose

The purpose of this ordinance is to establish minimum storm water management requirements and controls to protect and safeguard the general health, safety, and welfare of the public residing in watersheds within the City of Auburn MS4 Area. This ordinance seeks to meet that purpose through the following objectives:

1) To prevent accelerated soil erosion and to control storm water runoff resulting from land disturbing activities, both during and after construction.

2) To assure that property owners control the volume and rate of storm water runoff originating from their property so that surface water and groundwater quality is protected, soil erosion minimized and flooding potential reduced.

3) To restrict storm water runoff entering and leaving development sites to non-erosive velocities by requiring temporary and permanent soil erosion control measures.

4) To assure that soil erosion control and storm water runoff control systems are incorporated into site planning at an early stage in the planning and design process.

5) To eliminate the need for costly maintenance and repairs to roads, embankments, ditches, streams, lakes, wetlands, and storm water control facilities which are the result of excessive soil erosion and inadequate storm water runoff control.

6) To encourage the design and construction of storm water control systems which serve multiple purposes, including but not limited to flood prevention, water quality protection, wildlife habitat preservation, education, recreation, and wetlands protection.

7) To assure that all storm water control facilities will be properly designed, constructed, and maintained.

8) To provide for enforcement of this ordinance.

Compatibility with Other Permit and Ordinance Requirements

This ordinance is not intended to interfere with, abrogate, or annul any other ordinance, rule or regulation, statute, or other provision of law. The requirements of this ordinance should be considered minimum requirements, and where any provision of this ordinance imposes restrictions different from those imposed by any other ordinance, rule or regulation, or other provision of law, whichever provisions are more restrictive or impose higher protective standards for human health or the environment shall be considered to take precedence.

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Severability

If the provisions of any article, section, subsection, paragraph, subdivision, or clause of this ordinance shall be judged invalid by a court of competent jurisdiction, such order of judgment shall not affect or invalidate the remainder of any article, section, subsection, paragraph, subdivision, or clause of this ordinance.

Development of a Storm Water Best Management Practices (BMP) Technical Manual

The City of Auburn will furnish additional policy, criteria and information including specifications and standards, for the proper implementation of the requirements of this ordinance and will provide such information in the form of a Storm Water BMP Technical Manual. This manual will include a list of approved storm water BMPs, including specific design criteria and operation and maintenance requirements for each practice. The manual may be updated and expanded from time to time, at the discretion of the local review authority, based on improvements in engineering, science, monitoring, and local maintenance experience. Storm water treatment practices that are constructed in accordance with these design and sizing criteria will be presumed to meet the minimum water quality performance standards.

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Section 162.003
Definitions

Auburn, City of – means employees or representatives of the City of Auburn designated to enforce and administer this ordinance.

Best management practice (BMP) – means any structural or nonstructural control measure utilized to improve the quality and, as appropriate, reduce the quantity of storm water run-off. It includes schedules of activities, prohibitions of practice, treatment requirements, operation and maintenance procedures, use of containment facilities, land use planning, policy techniques, and other management practices.

Conveyance – means any structural process for transferring storm water between at least two (2) points. The term includes, but is not limited to, piping, ditches, swales, curbs, gutters, catch basins, channels, storm drains, and roadways.

DeKalb County – means employees or representatives of the DeKalb County, Indiana.

Department – refers to the Indiana Department of Environmental Management (IDEM).

Floatable – means any solid waste that, due to its physical characteristics, will float on the surface of water. For the purposes of this ordinance, the term does not include naturally occurring floatables, such as leaves or tree limbs.

Illicit discharge – means any discharge to an MS4 conveyance that is not composed entirely of storm water, except naturally occurring floatables, such as leaves or tree limbs. Sources of illicit discharges include sanitary wastewater, septic tank effluent, car wash wastewater, oil disposal, radiator flushing disposal, laundry wastewater, roadway accident spillage, and household hazardous wastes.

Impervious surface – means any surface that prevents storm water to readily infiltrate into the soils.

Individual National Pollutant Discharge Elimination System (NPDES) permit – means an NPDES permit issued to one (1) MS4 operator that contains requirements specific to that MS4 conveyance.

Larger common plan of development or sale – means a plan, undertaken by a single developer or a group of developers acting in concert, to offer lots for sale or lease where such land is contiguous, or is known, designed, purchased, or advertised as a common unit or by a common name, such land shall be presumed as being offered for sale or lease as part of a larger common plan. The term also includes phased construction by a single entity for its own use.

Maintenance Agreement – means a legally recorded document that acts as a property deed restriction, and which provides for long-term maintenance of storm water management practices.

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MS4 area – means a land area comprising one (1) or more places that receives coverage under one (1) NPDES storm water permit regulated by Rule 13 or 327 IAC 5-4-6(a)(4) and 327 IAC 5-4-6(a)(5).

MS4 operator – means the person responsible for development, implementation, or enforcement of the MCMs for a designated MS4 area.

Municipal separate storm sewer system (MS4) – means a conveyance or system of conveyances, including, but not limited to, roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels, or storm drains, that is:

(A) owned or operated by a:

(i) federal, state, city, City, county, district, association, or other public body (created by or pursuant to state law) having jurisdiction over storm water, including special districts under state law such as a sewer district, flood control district, or drainage district, or similar entity, or a designated and approved management agency under Section 208 of the Clean Water Act (33 U.S.C. 1288) that discharges into waters of the state; or
(ii) privately owned storm water utility, hospital, university, or college having jurisdiction over storm water that discharges into waters of the state;

(B) designed or used for collecting or conveying storm water;
(C) not a combined sewer; and
(D) not part of a publicly owned treatment works (POTW) as defined at 40 CFR 122.2.

Municipal, state, federal, or institutional refueling area – means an operating gasoline or diesel fueling area whose primary function is to provide fuel to either municipal, state, federal, or institutional equipment or vehicles.

Notice of deficiency letter (NOD letter) – means a written notification from the department indicating an MS4 entity's deficiencies in its NOI letter or SWQMP submittals.

Notice of intent letter (NOI letter) – means a written notification indicating an MS4 entity's intention to comply with the terms of Rule 13 in lieu of applying for an individual NPDES permit and includes information as required under sections 6 and 9 of Rule 13. It is the application for obtaining permit coverage under Rule 13.

Notice of sufficiency letter (NOS letter) – means a written notification from the department indicating that an MS4 entity has sufficiently provided the required information in its NOI letter or SWQMP submittals.

Notice of termination letter (NOT letter) – means a written notification from the department indicating that an MS4 entity has met the conditions to terminate its permit coverage under Rule 13.

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Pollutant – means anything that causes or contributes to pollution discharged into waterways. Pollutants may include, but are not limited to: paints, varnishes, and solvents; oil and other automotive fluids; non-hazardous liquid and solid wastes and yard wastes; refuse, rubbish, garbage, litter, or other discarded or abandoned objects, and accumulations, so that the same may cause or contribute to pollution; floatables; pesticides, herbicides, and fertilizers; hazardous substances and wastes; sewage, fecal coliform and pathogens; dissolved and particulate metals; animal wastes; wastes and residues that result from constructing a building or structure; and noxious or offensive matter of any kind. Also, but not limited to dredged spoil; incinerator residue, filter backwash; sewage; garbage; sludge; munitions; chemical wastes; solid wastes; toxic wastes; hazardous substances; biological materials; radioactive materials (except those regulated under the Atomic Energy Act of 1954, as amended; 42 U.S.C. 011, et seq., heat, wrecked or discarded equipment; rock; sand; cellar dirt; and other industrial, municipal, and agricultural waste; discharged into water.

Pollutant of concern – means any pollutant that has been documented via analytical data as a cause of impairment in any waterbody, or to another MS4, to which the MS4 discharges.

Responsible individual or party – means the person responsible for development, implementation, or enforcement of the MCMs for a designated MS4 entity.

Retail gasoline outlet – means an operating gasoline or diesel fueling facility whose primary function is the resale of fuels. The term applies to facilities that create five thousand (5,000) or more square feet of impervious surfaces or generate an average daily traffic count of one hundred (100) vehicles per one thousand (1,000) square feet of land area.

Soil and water conservation district (SWCD) – means a political subdivision established under IC 14-32.

Storm water – means water resulting from rain, melting or melted snow, hail, sleet or other natural occurrences.

Storm water quality management plan (SWQMP) – means a comprehensive written document that addresses storm water run-off quality within an MS4 area. The SWQMP is divided into three (3) different submittal parts as follows:

(A) Part A-Initial Application.
(B) Part B-Baseline Characterization and Report.
(C) Part C-Program Implementation.

Waters – means:

(A) the accumulations of water, surface and underground, natural and artificial, public and private; or

(B) a part of the accumulations of water; that are wholly or partially within flow through, or border upon Indiana. The term does not include a private pond, or an off stream pond,

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reservoir, or BMP built for reduction or control of pollution or cooling of water before discharge, unless the discharge from the pond, reservoir, or BMP causes or threatens to cause water pollution.

Watershed – means an area of land from which water drains to a common point.

Section 162.003
Applicability

The requirements under this ordinance are in compliance with 327 IAC 15-5 (Rule 5) and 327 IAC 15-13 (Rule 13). The storm water pollution prevention plan, which is submitted to the City of Auburn as part of the construction plan approval process, must include post-construction storm water quality measures. These measures are incorporated as a permanent feature into the site plan and are left in place following completion of construction activities to continuously store and/or treat storm water from the stabilized site. Any project located within the City of Auburn that includes clearing, grading, excavation, concrete or bituminous paving, and other land disturbing activities, resulting in the disturbance of or impact on one (1) acre or more of total land area, is subject to the requirements of this Ordinance. This includes both new development and re-development, and disturbances of less than one (1) acre of land that are part of a larger common plan of development or sale if the larger common plan will ultimately disturb one (1) or more acres of land, within the MS4 area.

The requirements under Rule 13 do not apply to persons who are involved in agricultural land disturbing activities or forest harvesting activities.

The requirements under Rule 13 do not apply to the following activities, provided other applicable permits contain provisions requiring immediate implementation of soil erosion control measures.

a. Landfills that have been issued a certification of closure under 329 IAC 10
b. Coal mining activities permitted under IC 14-34
c. Municipal solid waste landfills that are accepting waste pursuant to a permit issued by the Indiana Department of Environmental Management (IDEM) under 329 IAC 10 that contains equivalent storm water requirements, including the expansion of landfill boundaries and construction of new cell(s) either within or outside the original solid waste permit boundary
d. Road and regulated drain maintenance

It will be the responsibility of the project site owner and/or project site owner's designee to ensure proper construction and installation of all storm water BMPs in compliance with this Ordinance, and to notify the City of Auburn MS4 Operator with a notice of termination letter (NOT) upon completion of the project and stabilization of the site. However, all eventual property owners of storm water quality management facilities meeting the applicability requirements must comply with the requirements of this Ordinance.

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Section 162.004
Performance Criteria for Storm Water Management

Unless judged by the City of Auburn to be exempt, the following performance criteria shall be addressed for storm water management at all sites:

1) All site designs shall establish storm water management practices to control the peak flow rates of storm water discharge associated with specified design storms and reduce the generation of storm water. These practices should seek to utilize pervious areas for storm water treatment and to infiltrate storm water from driveways, sidewalks, rooftops, parking lots, and landscaped areas to the maximum extent practical to provide treatment for both water quality and quantity.
2) All storm water generated from new development shall not discharge untreated storm water directly into a receiving water body.
3) For new development, structural storm water treatment practices shall be designed to remove 80% of the average annual post development total suspended solids (TSS) load. It is presumed that a BMP complies with this performance standard if it is:
   a. Sized to capture the prescribed water quality volume (WQ).
   b. Designed according to the specific performance criteria outlined in the City of Auburn's Storm Water BMP Technical Manual,
   c. Constructed properly, and
   d. Maintained regularly.
4) The calculations for determining peak flows as found in the Storm Water BMP Technical Manual shall be used for sizing all storm water BMPs unless prior approval is received from the City of Auburn.
5) For sites that discharge to DeKalb County controlled drains the storm water BMP shall be designed to meet any applicable requirements in the DeKalb County Storm Water Control Ordinance and receive County Drainage Board approval if appropriate.
6) New retail gasoline or diesel fuel outlets, new municipal, state, federal, or institutional gasoline or diesel refueling areas, or new privately owned gasoline or diesel refueling areas, or existing gasoline or diesel outlets and refueling areas that replace their existing tanks or install additional new tanks must install appropriate BMPs to reduce lead, copper, zinc, and hydrocarbons in storm water.
7) Individual properties that have 5.0 acres or more of paved (asphalt, concrete, brick, stone pavers, or other impervious materials) area must install appropriate practices to reduce lead, copper, zinc, and hydrocarbons in storm water.
8) Infiltration practices are to be allowed in wellhead protection areas.
9) Vegetated filter strips are required along unvegetated swales and ditches.
10) Discharge from the MS4 conveyance into sinkholes or fractured bedrock without treatment that results in the discharge meeting Indiana groundwater quality standards as references in 327 IAC 2-11 are prohibited.
11) Discharges from storm water Class V injection must meet Indiana groundwater quality standards.

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Section 162.005
Storm Water Management Design Criteria

The specific storm water BMP design criteria are not detailed in this Ordinance. The detailed storm water management design criteria are provided in the City of Auburn's Storm Water BMP Technical Manual. The Storm Water BMP Technical Manual allows select design information to change over time as new information or techniques become available without requiring the formal process needed to change ordinance language. The Ordinance can then require those submitting any development application to consult the current Storm Water BMP Technical Manual for the exact design criteria for the storm water management practices appropriate for their site.

Approved BMP's are listed in the City of Auburn's Storm Water BMP Technical Manual. The approved BMPs must be designed, constructed, and maintained according to guidelines provided in the Storm Water BMP Technical Manual or as provided by the manufacturer of the storm water BMP. Practices other than those specified in the approved list may be utilized. However, the burden of proof, as to whether the performance (minimum 80% TSS removal) and ease of maintenance of such practices will be placed with the applicant. Details regarding the procedures and criteria for consideration of acceptance of such BMPs are available from the International Storm water Best Management Practices (BMP) Database developed by the Federal Highway Administration (FHWA) and the American Society of Civil Engineers (ASCE). The information and data is available at http://www.bmpdatabase.org.

Minimum Control Requirements

All storm water BMPs will be designed so that the specific storm frequency storage volumes to meet water quality and water quantity reduction requirements as identified in the current Storm Water BMP Technical Manual are met.

In addition, if hydrologic or topographic conditions warrant greater control than that provided by the control requirements present in the BMP Technical Manual, the City of Auburn reserves the right to impose any and all additional requirements deemed necessary to control the volume, timing, and rate of run off.

Site Design Feasibility

Storm water management practices for a site shall be chosen based on the physical conditions of the site. Among the factors that should be considered include:

1. Topography
2. Maximum Drainage Area
3. Depth to Water Table
4. Soils
5. Slopes
6. Terrain
7. Head
8. Location in relation to environmentally sensitive features or urban areas.

Applicants shall consult the Storm Water BMP Technical Manual for guidance on the factors that determine site design feasibility when selecting storm water BMPs

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Section 162.006
Requirements for Storm Water Management Plan Approval

The City shall review the Storm Water Pollution Prevention Plan (SWPPP) to determine whether the requirements of this ordinance and the City of Auburn Construction Site Run-Off Control located in Section 162 of the City of Auburn Municipal Code. If the City determines that the proposed SWPPP complies with the standards in the Construction Site Runoff Control and Post Construction Runoff Control Ordinances, a permit shall be issued specifying the work approved. If the proposed plan does not comply with these standards, the permit request shall be modified or denied. Upon request, the City will furnish the applicant or other interested persons with a statement in writing of the reasons for permit denial or approval. If necessary, the City may request additional information from the applicant.

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162.007
Construction Inspection

Notice of Construction Commencement

The applicant must notify the City of Auburn in advance before the commencement of construction of the BMP. The staff of the City of Auburn shall conduct regular inspections of the construction site. 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 storm water management plan;
3. Variations from the approved construction specifications; and
4. Any infractions of this ordinance that exist.

If any infractions are found, the property owner shall be notified in writing of the nature of the infraction and the required corrective actions. No added work shall proceed until any infractions are corrected and all work previously completed has received approval by the City of Auburn.

As Built Plans

All project site owners are required to submit "as built" plans for any storm water BMPs located on-site after final construction is completed. The plan must show the final design specifications for all storm water BMPs and must be certified by a professional engineer. A final inspection by the City of Auburn is required before the release of any performance securities can occur.

Landscaping and Stabilization Requirements

Any area of land from which the natural vegetative cover has been either partially or wholly cleared or removed by development activities shall be revegetated within fifteen (15) days from the substantial completion of such clearing and construction. The following criteria shall apply to revegetation efforts:

- 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.
- 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.
- Any area of revegetation must exhibit survival of a minimum of seventy percent (70%) of the cover crop throughout the year immediately following revegetation. Revegetation must be repeated in successive years until the minimum seventy percent (70%) survival for one (1) year is achieved.

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

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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. This plan must be prepared by a registered landscape architect or the owner of the real estate, with the approval of the local soil conservation district, and must be approved prior to receiving a permit.

Inspection Authority

After the approval of the Storm Water Management Plan by the City of Auburn and the commencement of construction activities, the City of Auburn has the authority to conduct inspections of the work being done to ensure full compliance with the provisions of this Ordinance and the terms and conditions of the approved permit.

The City of Auburn has the authority to perform long-term, post-construction inspection of all public or privately owned BMPs. The inspections will follow the Operation and Maintenance procedures included in the Storm Water BMP Technical Manual and/or permit application for each specific BMP. The inspection will cover physical conditions, available water quality storage capacity, and the operational condition of key BMP elements but is not limited to these items. Noted deficiencies and recommended corrective actions will be included in an inspection report. If deficiencies are found during the inspection, the owner of the BMP will be notified by the City of Auburn and will be required to take all necessary measures to correct such deficiencies. If the owner fails to correct the deficiencies within the allowed time period, as specified in the notification letter, the City of Auburn will undertake the work and collect from the owner using lien rights if necessary.

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Section 162.008
Monitoring, Maintenance, and Repair of Storm Water Facilities

Monitoring Requirements

The City of Auburn may require monitoring of the discharge from a BMP if
- (A) Illicit Discharges to the BMP have been detected;
- (B) Maintenance problems have been noted; and/or
- (C) Complaints have been received from City residents

Monitoring required may include the following:
- (A) Routine visual monitoring of dry weather flows;
- (B) Routine visual monitoring of premises for spills or pollutant discharges;
- (C) A log of monitoring dates, potential pollution sources noted above, and mitigation measures taken; and/or
- (D) Laboratory analyses for pollutants, if determined to be necessary.

Required monitoring may be discontinued after conditions requiring monitoring no longer exist and the City of Auburn has been provided written notice prior to cessation. The required activity may not cease if written notice to continue is issued by the City of Auburn.

Maintenance Easement

Prior to the issuance of any permit that has a BMP as one of the requirements of the permit, the applicant or owner of the site must execute a maintenance easement agreement that shall be binding on all subsequent owners of land served by the BMP. The agreement shall provide for access to the BMP at reasonable times for periodic inspection by the City of Auburn, or their designated representative, to ensure that the BMP is maintained in proper working condition to meet design standards and any other provisions established by this ordinance. The easement agreement shall be recorded by the City of Auburn in the land records.

Maintenance Covenants

Maintenance of all storm water BMPs shall be ensured through the creation of a formal maintenance covenant that must be approved by the City of Auburn and recorded into the land record prior to final plan approval. As part of the covenant, a schedule shall be developed for when and how often maintenance will occur to ensure proper function of the BMP.

The covenant shall also include plans for periodic inspections to ensure proper performance of the BMP between scheduled cleanouts, any and all maintenance easements required to access and inspect the storm water BMPs, and to perform routine maintenance as necessary to ensure proper functioning.

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The City of Auburn, in lieu of a maintenance covenant, may accept dedication of any existing or future storm water BMP for maintenance, provided such BMP meets all the requirements of this Ordinance and includes adequate and perpetual access and sufficient area, by easement or otherwise, for inspection and regular maintenance.

Inspection of Storm Water BMPs

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 infractions of this Ordinance. All storm water management BMPs must undergo, at the minimum, an annual inspection to document maintenance and repair needs and ensure compliance with the requirements of this Ordinance and accomplishment of its purposes. Inspections may include, but are not limited to: reviewing maintenance and repair records; sampling discharges, surface water, groundwater, and material or water in BMPs; and evaluating the condition of storm water BMPs.

Any maintenance needs found must be addressed in a timely manner, as determined by the City of Auburn, and the inspection and maintenance requirement may be increased as deemed necessary to ensure proper functioning of the storm water BMP.

Right-of-Entry for Inspection

When any new storm water BMP is installed on private property, or when any new connection is made between private property and a public storm sewer conveyance, sanitary sewer or combined sewer, the property owner shall grant to the City of Auburn the right to enter the property at reasonable times and in a reasonable manner for the purpose of inspection. This includes the right to enter a property when it has a reasonable basis to believe that an infraction of this ordinance is occurring or has occurred, and to enter when necessary for abatement of a public nuisance or correction of an infraction of this ordinance.

Records of Installation and Maintenance Activities

Parties responsible for the operation and maintenance of storm water BMPs shall make records of the installation and of all maintenance and repairs, and shall retain the records for at least 5 (five) years. These records shall be made available to the City of Auburn during the inspection of the BMP and at other reasonable times upon request.

Failure to Maintain Practices

If a responsible party fails or refuses to meet the requirements of the maintenance covenant, the City of Auburn, after reasonable notice, may correct a violation of the design standards or maintenance needs by performing all necessary work to place the BMP in proper working condition. In the event that the storm water BMP becomes a danger to public safety or public health, the City of Auburn shall notify the party responsible for maintenance of the storm water BMP in writing. Upon receipt of that notice, the responsible person shall have fourteen (14) days to conduct maintenance

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and repair of the BMP in an approved manner. After proper notice, the City of Auburn may assess the owner(s) of the BMP for the cost of repair work and any penalties; and the cost of the work shall be a lien on the property, or prorated against the beneficial users of the property, and may be placed on the tax bill and collected as ordinary taxes by the county.

APPENDIX B

CONSTRUCTION BMP INFORMATION
INDIANA HANDBOOK FOR EROSION CONTRO
IN DEVELOPING AREAS

INDIANA HANDBOOK FOR EROSION CONTROL IN DEVELOPING AREAS

Guidelines for Protecting Water Quality Through the Control of Soil Erosion and Sedimentation on Construction Sites

Published by the

DIVISION OF SOIL CONSERVATION, INDIANA DEPARTMENT OF NATURAL RESOURCES

in cooperation with the

Soil Conservation Service, U.S. Department of Agriculture
Purdue University Cooperative Extension Service
Indiana Association of Soil and Water Conservation Districts, Inc.
Indiana Department of Environmental Management
U.S. Environmental Protection Agency

October 1992

Contents

Acknowledgements and Disclaimer

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Much of the material presented here was adapted from similar development site erosion and sediment control manuals published by these agencies/organizations in other states:

* Association of Illinois Soil and Water Conservation Districts.
* Minnesota Board of Water and Soil Resources.
* Empire State Chapter (New York), Soil and Water Conservation Society.
* Division of Land Resources, North Carolina Department of Environment, Health and Natural Resources.
* Soil Conservation Service, U.S.D.A., Ohio.
* Nonpoint Source and Land Management Section, Bureau of Water Resource Management, Wisconsin Department of Natural Resources.

Of the 114 pictures and design drawing "exhibits" in this manual, 60 were provided by IDNR Soil Conservation and USDA/SCS (Indiana) and the following 54 by these agencies, organizations, and commercial firms with their permission:

NuTec Supply Co.--*3.17-B* and *3.18-A*. North Carolina Department of Environment, Health, and Natural Resources--*3.01-A, 3.01-B, 3.01-C, 3.03-B, 3.03-C, 3.03-E, 3.14-D, 3.16-B, 3.21-A, 3.21-B, 3.22-B, 3.23-A, 3.23-B, 3.23-C, 3.24-A, 3.24-D, 3.25-B, 3.25-C, 3.26-C, 3.26-D, 3.32-B, 3.41-A, 3.41-B, 3.51-A, 3.51-B, 3.51-C, 3.52-B, 3.52-C, 3.53-A, 3.53-B, 3.53-C, 3.56-B, 3.71-B, 3.71-C, 3.72-B, 3.72-C, 3.74-E, 3.76-A, 3.76-B, 3.76-C, 3.82-A*, and *3.82-B*. Empire State (NY) Soil and Water Conservation Society--*3.24-B*. Oklahoma County Conservation District--*3.03-D*. USDA Soil Conservation Service (Ohio)--*3.54-B, 3.61-B, 3.61-C, 3.62-B*, and *3.62-C*. Wisconsin Department of Natural Resources--*3.63-A, 3.63-B*, and *3.64-B*.

The U.S. Environmental Protection Agency provided a grant to cover a portion of the cost of developing and distributing this handbook.

Introduction

Whenever vegetation is removed from land, the soil becomes exposed to the erosive effects of wind and water. Although erosion is a natural process, it can be greatly accelerated by man's action in disturbing the land's surface.

Two major land-disturbing activities in Indiana are agriculture and urban development. Both are very important to the economic well-being of all the citizens of the state. Although the total tons of soil eroded is greater for agriculture, the amount of soil eroded on a per-acre basis during urban development can be many times greater.

The building of residential subdivisions, shopping centers, industrial parks, schools, recreational attractions, etc. significantly affects patterns and amounts of stormwater runoff during and after construction takes place. Soil erosion not only causes on-site damage problems, but also can negatively impact water quality downstream through sediment pollution.

This handbook provides contractors, builders, developers, governmental officials, and others with guidelines and specific practices for controlling soil erosion and the non-point source pollution associated with the sediment in runoff. Adhering to these guidelines and properly applying the appropriate practices will help minimize the adverse impacts of development on the water and soil resources and, ultimately, the cost of those impacts to society as a whole.

The handbook is divided into the following three sections plus appendices:

* Section 1 reproduces the state's new rule (327 IAC 15-5) governing its construction activities permits program, administered by the Indiana Department of Environmental Management. It applies to construction sites with five acres or more of disturbed land.

* Section 2 covers (a) ten principles that provide an overall strategy for controlling erosion and sedimentation in areas undergoing land-disturbing activities; (b) basic content of an erosion and sediment control plan; and (c) development of a construction sequence schedule that utilizes the erosion/sediment control plan.

* Section 3 describes and shows various urban erosion and sediment control practices, including their purpose, requirements, installation, maintenance, and common concerns. The descriptions do not emphasize the engineering aspects, but rather how each practice best "works with the landscape" to control erosion and sedimentation. Engineering designs are usually site-specific and may be provided by a private engineering firm, city engineering department, the USDA Soil Conservation Service, or other source of expertise.

* The Appendices contain a glossary of common terms, technical information on various erosion control practices and materials, symbols for use on erosion/sediment control plan site maps, and a listing of Indiana's 92 Soil & Water Conservation Districts.

Periodic review and update of this handbook is planned. If you wish to receive the new and revised material as it becomes available, please fill out and return the ivory-colored form immediately inside the back cover. Any comments, questions, or suggestions concerning this handbook should be directed to:

DNR

Urban Conservation Program
Division of Soil Conservation
Indiana Department of Natural Resources
402 West Washington Street, Room W-265
Indianapolis, IN 46204-2748
Telephone (317) 233-3870 FAX (317) 233-3882

Section 1

RULE 5: Stormwater Runoff Associated with Construction Activity

- ⇨ **Information about the Rule**
- ⇨ **How to Comply with the Rule**
- ⇨ **Copy of the Rule**

Phase I of this Rule applied to all persons involved in construction activity (which includes clearing, grading, and excavating) that resulted in the disturbance of five (5) acres or more of land area.

Under Phase II of the program, this rule's applicability requirements were extended to construction activities disturbing one (1) or more acres of land area. The inclusion of a lower disturbance threshold will further reduce the amount of sediment (a leading cause of impairment in rivers and lakes) and other pollutants associated with construction site run-off.

Rule 5 is administered by the Indiana Department of Environmental Management, Office of Water Quality in cooperation with the Indiana Department of Natural Resources, Division of Soil Conservation and Indiana's Soil and Water Conservation Districts.

- ⇨ For questions regarding permit administration, filing a Notice of Intent, etc.
  - Contact IDEM's Rule 5 Coordinator at (317)233-1864.

- ⇨ For questions regarding development of a Stormwater Pollution Prevention Plan, Plan Review, Site Inspections, etc.
  - Contact the Soil and Water Conservation District (SWCDs are located in each County in Indiana) or the Division of Soil Conservation of the DNR (317-233-3870).

Additional information on the Rule, Procedures, and Forms can be found on the following websites:

- ⇨ Indiana Department of Environmental Management: http://www.in.gov/idem/water/npdes/permits/wetwthr/storm/rule5.html

- ⇨ Indiana Department of natural Resources, Division of Soil Conservation: http://www.in.gov/dnr/soilcons/

Staying in compliance with Phase II - 327 IAC 15-5

Step 1: Develop a Construction Plan, including the Storm Water Pollution Prevention Plan (Evaluate the site, review the rule requirements, utilize the *Indiana Handbook for Erosion Control in Developing Areas (this manual will be re-named and updated within the next year, the new name will be the* *Indiana Stormwater Quality Manual* and will include an updated section on planning principles and post construction water quality practices)

Step 2: Submit the Construction Plan to the reviewing authority for review *(The reviewing authority has up to 28 days from the date of submittal to review the plan. If the project site owner has not received notification that the plan is deficient within the 28-day review period, the NOI letter may be submitted to IDEM. If notice of a deficient plan is received, the plans must be revised to satisfy the deficiencies and resubmitted to the reviewing authority, at which time the 28-day review period starts over)*

Step 3: Receive Construction Plan approval from reviewing authority *(Modifications to the plan may be requested by the reviewing authority before approval is granted)*

Step 4: Submit Notice of Intent (NOI) letter to IDEM a minimum of 48 hours prior to initiation of land disturbing activities. A complete NOI letter submittal must include:

1. Proof of Publication
2. Proof of Construction Plan approval, or expiration of the 28-day review period from the reviewing authority
3. $100 general permit filing fee

Step 5: Begin construction activities *(Construction activities may not begin prior to Construction Plan approval and submittal of NOI letter. The project site owner must also notify IDEM and the reviewing authority of the actual start date within 48 hours of starting land disturbing activities.)*

Step 6: Implement the approved Construction Plan throughout construction *(revise the plan and make changes on the project site, as necessary, to prevent pollutants, including sediment, from leaving the project site. Communicate with the reviewing/inspecting authority, especially when significant changes are made.)*

Step 7: Submit a Notice of Termination (NOT) request [PDF]. The project site owner must:

1. Prepare a complete NOT, with all required supporting documentation
2. Receive verification from the local reviewing authority (SWCD or other entity designated by IDEM) that the project meets the termination requirements as specified in Rule 5.
3. Once verified by the local reviewing authority, submit the NOT form to IDEM for final approval.

Rule 5. Storm Water Run-Off Associated with Construction Activity

327 IAC 15-5-1 Purpose
Authority: IC 13-14-8; IC 13-14-9; IC 13-15-1-2; IC 13-15-2-1; IC 13-18-3
Affected: IC 13-11-2; IC 13-18-4

Sec. 1. The purpose of this rule is to establish requirements for storm water discharges from construction activities of one (1) acre or more so that the public health, existing water uses, and aquatic biota are protected.

(Water Pollution Control Board; 327 IAC 15-5-1; filed Aug 31, 1992, 5:00 p.m.: 16 IR 23; errata, 16 IR 898; readopted filed Jan 10, 2001, 3:23 p.m.: 24 IR 1518; filed Oct 27, 2003, 10: 15 a.m.: 27 IR 833)

327 IAC 15-5-2 Applicability of general permit rules
Authority: IC 13-14-8; IC 13-14-9; IC 13-15-1-2; IC 13-15-2-1; IC 13-18-3
Affected: IC 13-11-2; IC 13-18-4; IC 14-34

Sec. 2. (a) The requirements under this rule apply to all persons who:
(1) do not obtain an individual NPDES permit under 327 IAC 15-2-6;
(2) meet the general permit rule applicability requirements under 327 IAC 15-2-3; and
(3) are involved in construction activity, except operations that result in the land disturbance of less than one (1) acre of total land area as determined under subsection (h) and are not part of a larger common plan of development or sale.

(b) The requirements under this rule do not apply to persons who are involved in:
(1) agricultural land disturbing activities; or
(2) forest harvesting activities.

(c) The requirements under this rule do not apply to the following activities, provided other applicable permits contain provisions requiring immediate implementation of soil erosion control measures:
(1) Landfills that have been issued a certification of closure under 329 IAC 10.
(2) Coal mining activities permitted under IC 14-34.
(3) Municipal solid waste landfills that are accepting waste pursuant to a permit issued by the department under 329 IAC 10 that contains equivalent storm water requirements, including the expansion of landfill boundaries and construction of new cells either within or outside the original solid waste permit boundary.

(d) The project site owner has the following responsibilities:
(1) Complete a sufficient notice of intent letter.
(2) Ensure that a sufficient construction plan is completed and submitted in accordance with section 6 of this rule.
(3) Ensure compliance with this rule during:
(A) the construction activity; and
(B) implementation of the construction plan.
(4) Notify the department with a sufficient notice of termination letter.
(5) Ensure that all persons engaging in construction activities on a permitted project site comply with the applicable requirements of this rule and the approved construction plan.

(e) For off-site construction activities that provide services (for example, road extensions, sewer, water, and other utilities) to a permitted project site, these off-site activity areas must be considered a part of the permitted project site when the activity is under the control of the project site owner.

(f) For an individual lot where land disturbance is expected to be one (1) acre or more and the lot lies within a project site permitted under this rule, the individual lot owner shall:
(1) complete his or her own notice of intent letter; and
(2) ensure that a sufficient construction plan is completed and submitted in accordance with section 6 of this rule.

(g) For an individual lot where the land disturbance is less than one (1) acre and the lot lies within a project site permitted under this rule, the individual lot operator shall be in accordance with the following:
(1) Comply with:
(A) the provisions and requirements of the plan developed by the project site owner; and
(B) section 7.5 of this rule.
(2) Does not need to submit a notice of intent letter and construction plans.

(h) Multi-lot project sites are regulated by this rule in accordance with the following:

(1) A determination of the area of land disturbance shall be calculated by adding the total area of land disturbance fc improvements, such as roads, utilities, or common areas, and the expected total disturbance on each individual lot, as determined by the following:

(A) For a single-family residential project site where the lots are one-half (0.5) acre or more, one-half (0.5) acre of land disturbance must be used as the expected lot disturbance.

(B) For a single-family residential project site where the lots are less than one-half (0.5) acre in size, the total lot must be calculated as being disturbed.

(C) To calculate lot disturbance on all other types of project sites, such as industrial and commercial project sites, the following apply:

(i) Where lots are one (1) acre or greater in size, a minimum of one (1) acre of land disturbance must be calculated as the expected lot disturbance.

(ii) Where the lots are less than one (1) acre in size, the total lot must be calculated as being disturbed.

(2) For purposes of this rule, strip developments:

(A) are considered as one (1) project site; and

(B) must comply with this rule; unless the total combined disturbance on all individual lots is less than one (1) acre and is not part of a larger common plan of development or sale.

(i) Submittal of a notice of intent and construction plans is not required for construction activities associated with single-family residential dwelling disturbing less than five (5) acres when the dwelling is not part of a larger common plan of development or sale. Provisions in section 7(b) (1) through 7(b) (5), 7(b) (10) through 7(b) (17), 7(b) (19), and 7(b) (20) of this rule shall be complied with throughout construction activities and until the areas are permanently stabilized.

(j) The department may waive the permit requirements under this rule for construction activities that disturb less than five (5) acres where the waiver applicant determined by the commissioner certifies that:

(1) a total maximum daily load (TMDL) for the pollutants of concern from storm water discharges associated with construction activity indicates that controls on construction site discharges are not needed to protect water quality; or

(2) in receiving waters that do not require a TMDL study, an equivalent analysis demonstrates water quality is not threatened by storm water discharges, and it has been determined that allocations for the pollutants of concern from the construction site discharges are not needed to protect water quality based on consideration of existing in-stream concentrations, expected growth in pollutant contributions from all sources, and a margin of safety.

(Water Pollution Control Board; 327 IAC 15-5-2; filed Aug 31, 1992, 5:00 p.m.: 16 IR 23; readopted filed Jan 10, 2001, 3:23 p.m.: 24 IR 1518; filed Oct 27, 2003, 10:15 a.m.: 27 IR 833)

327 IAC 15-5-3 **General permit rule boundary**
Authority: **IC 13-14-8; IC 13-14-9; IC 13-15-1-2; IC 13-15-2-1; IC 13-18-3**
Affected: **IC 13-11-2; IC 13-18-4**

Sec. 3. This general permit covers all lands within Indiana. (Water Pollution Control Board; 327IAC 15-5-3; filed Aug 31, 1992, 5:00 p.m.: 16 IR 23; readopted filed Jan 10, 2001, 3:23 p.m.: 24 IR 1518; filed act 27, 2003, 10: 15 a.m.: 27 IR 834)

327 IAC 15-5-4 **Definitions**
Authority: **IC 13-14-8; IC 13-14-9; IC 13-15-1-2; IC 13-15-2-1; IC 13-18-3**
Affected: **IC 13-11-2; IC 14-32; IC 14-34**

Sec. 4. In addition to the definitions contained in IC 13-11-2, 327 IAC 1, 327 IAC 5, and 327 IAC 15-1-2, the following definitions apply throughout this rule:

(1) "Agricultural conservation practices" means practices that are constructed on agricultural land for the purposes of controlling soil erosion and sedimentation. These practices include grass waterways, sediment basins, terraces, and grade stabilization structures.

(2) "Agricultural land disturbing activity" means tillage, planting, cultivation, or harvesting operations for the production of agricultural or nursery vegetative crops. The term also includes pasture renovation and establishment, the construction of agricultural conservation practices, and the installation and maintenance of agricultural drainage tile. For purposes of this rule, the term does not include land disturbing activities for the construction of agricultural related facilities, such as:
(A) barns;
(B) buildings to house livestock;
(C) roads associated with infrastructure;
(D) agricultural waste lagoons and facilities;
(E) lakes and ponds;
(F) wetlands; and
(G) other infrastructure.

(3) "Commissioner" refers to the commissioner of the department.

(4) "Construction activity" means land disturbing activities and land disturbing activities associated with the construction of infrastructure and structures. This term does not include routine ditch or road maintenance or minor landscaping projects.

(5) "Construction plan" means a representation of a project site and all activities associated with the project. The plan includes the location of the project site, buildings and other infrastructure, grading activities, schedules for implementation, and other pertinent information related to the project site. A storm water pollution prevention plan is a part of the construction plan.

(6) "Construction site access" means a stabilized stone surface at all points of ingress or egress to a project site for the purpose of capturing and detaining sediment carried by tires of vehicles or other equipment entering or exiting the project site.

(7) "Contractor" or "subcontractor" means an individual or company hired by the project site or individual lot owner, their agent, or the individual lot operator to perform services on the project site.

(8) "Department" refers to the department of environmental management.

(9) "Developer" means:
(A) any person financially responsible for construction activity; or
(B) an owner of property who sells or leases, or offers for sale or lease, any lots in a subdivision.

(10) "DNR-DSC" means the division of soil conservation of the department of natural resources.

(11) "Erosion" means the detachment and movement of soil, sediment, or rock fragments by water, wind, ice, or gravity.

(12) "Erosion and sediment control measure" means a practice, or a combination of practices, to control erosion and resulting sedimentation.

(13) "Erosion and sediment control system" means the use of appropriate erosion and sediment control measures to minimize sedimentation by first reducing or eliminating erosion at the source and then, as necessary, trapping sediment to prevent it from being discharged from or within a project.

(14) "Final stabilization" means the establishment of permanent vegetative cover or the application of a permanent nonerosive material to areas where all land disturbing activities have been completed and no additional land disturbing activities are planned under the current permit.

(15) "grading" means the cutting and filling of the land surface to a desired slope or elevation.

(16) "Impervious surface" means surfaces, such as pavement and rooftops, that prevent the infiltration of storm water into the soil.

(17) "Individual building lot" means a single parcel of land within a multi-parcel development.
(18) "Individual lot operator" means a contractor or subcontractor working on an individual lot.
(19) "Individual lot owner" means a person who has financial control of construction activities for an individual lot.
(20) "Land disturbing activity" means any manmade change of the land surface, including removing vegetative cover that exposes the underlying soil, excavating, filling, transporting, and grading.
(21) "Larger common plan of development or sale" means a plan, undertaken by a single project site owner or a group of project site owners acting in concert, to offer lots for sale or lease; where such land is contiguous, or is known, designated, purchased or advertised as a common unit or by a common name, such land shall be presumed as being offered for sale or lease as part of a larger common plan. The term also includes phased or other construction activity by a single entity for its own use.
(22) "Measurable storm event" means a precipitation event that results in a total measured precipitation accumulation equal to, or greater than, one-half (0.5) inch of rainfall.
(23) "MS4 area" means a land area comprising one (1) or more places that receives coverage under one (1) NPDES storm water permit regulated by 327 IAC 15-13 or 327 IAC 5-4-6(a)(4) and 327 IAC 5-4-6(a)(5).
(24) "MS4 operator" means the person responsible for development, implementation, or enforcement of the minimum control measures for a designated MS4 area regulated under 327 IAC 15-13.
(25) "Municipal separate storm sewer system" or "MS4" has the same meaning set forth at 327 IAC 15-13-5(42).
(26) "Peak discharge' means the maximum rate of flow during a storm, usually in reference to a specific design storm event.
(27) "Permanent stabilization" means the establishment, at a uniform density of seventy percent (70%) across the disturbed area, of vegetative cover or permanent nonerosive material that will ensure the resistance of the soil to erosion, sliding, or other movement.
(28) "Phasing of construction" means sequential development of smaller portions of a large project site, stabilizing each portion before beginning land disturbance on subsequent portions, to minimize exposure of disturbed land to erosion.
(29) "Project site" means the entire area on which construction activity is to be performed.
(30) "project site owner" means the person required to submit the NOI letter under this article and required to comply with the terms of this rule, including either of the following:
  (A) A developer.
  (B) A person who has financial and operational control of construction activities and project plans and specifications, including the ability to make modifications to those plans and specifications.
(31) "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.
(32) "Sedimentation" means the settling and accumulation of unconsolidated sediment carried by storm water run-off.
(33) "Soil" means the unconsolidated mineral and organic material on the surface of the earth that serves as the natural medium for the growth of plants.
(34) "Soil and Water Conservation District" or "SWCD" means a political subdivision established under IC 14-32.
(35) "Storm water pollution prevention plan" means a plan developed to minimize the impact of storm water pollutants resulting from construction activities.
(36) "Storm water quality measure" means a practice, or a combination of practices to control or minimize pollutants associated with storm water run-off.
(37) "Strip development" means a multi-lot project where building lots front on an existing road.
(38) "Subdivision" means any land that is divided or proposed to be divided into lots, whether contiguous or subject to zoning requirements, for the purpose of sale or lease as part of a larger common plan of development or sale.
(39) "Temporary stabilization" means the covering of soil to ensure its resistance to erosion, sliding, or other movement. The term includes vegetative cover, anchored mulch, or other nonerosive material applied at a uniform density of seventy percent (70%) across the disturbed area.
(40) "Tracking" means the deposition of soil that is transported from one (1) location to another by tires, tracks of vehicles, or other equipment.
(41) "Trained individual" means an individual who is trained and experienced in the principles of storm water quality, including erosion and sediment control as may be demonstrated by state registration, professional certification, experience, or completion of coursework that enable the individual to make judgments regarding storm water control or treatment and monitoring.

(Water Pollution Control Board; 327 IAC 15-5-4; filed Aug 31, 1992, 5:00 p.m.: 16 IR 23; readopted filed Jan 10, 2001, 3:23 p.m.: 24 IR 1518; filed Oct 27, 2003, 10:15 a.m.: 27 IR 834; errata filed Feb 4, 2004, 1:45 p.m.: 27 IR 2284)

327 IAC 15-5-5 Notice of intent letter requirements
Authority: IC 13-14-8; IC 13-15-1-2; IC 13-15-2; IC 13-18-3; IC 13-18-4
Affected: IC 13-12-3-1; IC 13-18-1

Sec. 5. (a) The following information must be submitted by the project site owner with a complete NOI letter under this rule:

(1) Name, mailing address, and location of the project site for which the notification is submitted.
(2) The project site owner's name, address, telephone number, e-mail address (if available), ownership status as federal, state, public, private, or other entity.
(3) Contact person (if different than project site owner), person's name, company name, address, e-mail address (if available), and telephone number.
(4) A brief description of the construction project, including a statement of the total acreage of the project site. Total acreage claimed in the NOI letter shall be consistent with the acreage covered in the construction plan.
(5) Estimated dates for initiation and completion of construction activities. Within forty-eight (48) hours of the initiation of construction activity, the project site owner must notify the commissioner and the appropriate plan reviewing agency of the actual project start date.
(6) The latitude and longitude of the approximate center of the project site to the nearest fifteen (15) seconds, and the nearest quarter section, township, range, and civil township in which the project site is located.
(7) Total impervious surface area, in square feet, of the final project site including structures, roads, parking lots, and other similar improvements.
(8) The number of acres to be involved in the construction activities.
(9) Proof of publication in a newspaper of general circulation in the affected area that notified the public that a construction activity is to commence, that states, "(Company name, address) is submitting an NOI letter to notify the Indiana Department of Environmental Management of our intent to comply with the requirements under 327 IAC 15-5 to discharge storm water from construction activities for the following project: (name of the construction project, address of the location of the construction project). Run-off from the project site will discharge to (stream(s) receiving the discharge(s))".
(10) As applicable, a list of all MS4 areas designated under 327 IAC 15-13 within which the project site lies.
(11) A written certification by the operator that:
   (A) the storm water quality measures included in the construction plan comply with the requirements under sections 6.5, 7, and 7.5 of this rule and that the storm water pollution prevention plan complies with all applicable federal, state, and local storm water requirements;
   (B) the measures required by section 7 of this rule will be implemented in accordance with the storm water pollution prevention plan;
   (C) if the projected land disturbance is one (1) acre or more, the applicable soil and water conservation district or other entity designated by the department has been sent a copy of the construction plan for review;
   (D) storm water quality measures beyond those specified in the storm water pollution prevention plan will be implemented during the life of the permit if necessary to comply with section 7 of this rule; and
   (E) implementation of storm water quality measures will be inspected by trained individuals.
(12) The name of receiving water or, if the discharge is to a municipal separate storm sewer, the name of the municipal operator of the storm sewer and the ultimate receiving water.
(13) The NOI letter must be signed by a person meeting the signatory requirements in 327 IAC 15-4-3(g).
(14) A notification from the SWCD, DNR-DSC, or other entity designated by the department as the reviewing agency indicating that the constructions plans are sufficient to comply with this rule. This requirement may be waived if the project site owner has not received notification from the reviewing agency within the time frame specified in 327 IAC 15-5-6(b)(3).

(b) Send NOI letters to:

Attention: Rule 5 Storm Water Coordinator
Indiana Department of Environmental Management
Office of Water Quality, Urban Wet Weather Section
100 North Senate Avenue
P.O. Box 6015
Indianapolis, Indiana 46206-6015.

(Water Pollution Control Board; 327 IAC 15-5-5; filed Aug 31, 1992, 5:00 p.m.: 16IR 24; errata filed Sep 10, 1992, 12:00 p.m.: 16IR 65; readopted filed Jan 10, 2001, 3:23 p.m.: 24 IR 1518; filed Oct 27, 2003, 10: 15 a.m.: 27 IR 836)

327 IAC 15-5-6 Submittal of an NOI letter and construction plans
Authority: IC 13-14-8; IC 13-15-1-2; IC 13-15-2; IC 13-18-3; IC 13-18-4
Affected: IC 13-12-3-1; IC 13-18-1

Sec. 6. (a) After the project site owner has received notification from the reviewing agency that the construction plans meet the requirements of the rule or the review period outlined in subsection (b)(3) has expired. all NO I letter information required under section 5 of this rule shall be submitted to the commissioner at least forty-eight (48) hours prior to the initiation of land disturbing activities at the site. A copy of the completed NOI letter must also be submitted to all SWCDs, or other entity designated by the department, where the land disturbing activities are to occur. If the NOI letter is determined to be deficient, the project site owner must address the deficient items and submit an amended NOI letter to the commissioner at the address specified in section 5 of this rule.

(b) For a project site where the proposed land disturbance is one (1) acre or more as determined under section 2 of this rule, the following requirements must be met:

(1) A construction plan must be submitted according to the following:

(A) Prior to the initiation of any land disturbing activities.

(B) Sent to the appropriate SWCD or other entity designated by the department for:

(i) review and verification that the plan meets the requirements of the rule; or

(ii) a single coordinated review in accordance with subsection (d) (3) if:

(AA) the construction activity will occur in more than one (I) SWCD; and

(BB) the project site owner has made a request for a single coordinated review.

(2) If the construction plan required by subdivision (1) is determined to be deficient, the SWCD, DNR-DSC, or other entity designated by the department as the reviewing agency may require modifications, terms, and conditions as necessary to meet the requirements of the rule. The initiation of construction activity following notification by the reviewing agency that the plan does not meet the requirements of the rule is a violation and subject to enforcement action. If notification of a deficient plan is received after the review period outlined in subdivision (3) and following commencement of construction activities, the plans must be modified to meet the requirements of the rule and resubmitted within fourteen (14) days of receipt of the notification of deficient plans.

(3) If the project site owner does not receive notification within twenty-eight (28) days after the plan is received by the reviewing agency stating that the reviewing agency finds the plan is deficient, the project site owner may submit the NOI letter information.

(c) The following apply for a project were construction activity occurs inside a single MS4 area regulated under 327 IAC 15-13:

(1) A copy of the completed NOI letter must be submitted to the appropriate MS4 operators.

(2) The project site owner must comply with all appropriate ordinances and regulations within the MS4 area related to storm water discharges. The MS4 operator ordinance as required by 327 IAC 15-13-15(b) and 327 IAC 15-13-16(b) will be considered to have the same authority as this rule within the regulated MS4 area.

(d) For a project that will occur in more than one (l) jurisdiction, such as an SWCD or regulated MS4 area, the following must be met:

(1) Project site owners of project sites occurring in multiple MS4 areas, but not in nondesignated areas, shall submit the information required in subsection (c) to each appropriate MS4 operator.

(2) Project site owners of project sites occurring in one (1) or more MS4 areas and nondesignated areas shall submit the information required in subsections (a) through (c) to all appropriate MS4 operators, and the SWCD or other entity designated by the department.

(3) Project site owners of project sites occurring in multiple nondesignated areas, but not occurring within an MS4 area, may request a single coordinated review through the DNR-DSC office at the following address:
402 West Washington Street
Room W265
Indianapolis, Indiana 46204.

Upon acceptance of the request, the DNR-DSC will coordinate the plan review with appropriate SWCDs and other entities designated by the department.

(Water Pollution Control Board; 327 IAC 15-5-6 .filed Aug 31, 1992, 5;00p.m.; 16IR24; readopted .filed Jan 10, 2001, 3;23 p.m.; 24 IR 1518; .filed act 27, 2003, 10; 15 a.m.; 27 IR 837; errata .filed Feb 4, 2004, 1 ;45 p.m.; 27 IR2284)

327 IAC 15-5-6.5 Requirements for construction plans
Authority: IC 13-14-8; IC 13-15-1-2; IC 13-15-2; IC 13-18-3; IC 13-18-4
Affected: IC 13-12-3-1; IC 13-18-1

Sec. 6.5. (a) For project sites that do not meet the criteria in subsection (b), the project site owner shall develop a set of construction plans. Storm water quality measures included in the plan must achieve the minimum project site requirements specified in section 7 of this rule. The construction plans must include the following:

(1) Project narrative and supporting documents, including the following information:
  (A) An index indicating the location, in the construction plans, of all information required by this subsection.
  (B) Description of the nature and purpose of the project.
  (C) Legal description of the project site. The description should be to the nearest quarter section, township, and range, and include the civil township.
  (D) Soil properties, characteristics, limitations, and hazards associated with the project site and the measures that will be integrated into the project to overcome or minimize adverse soil conditions.
  (E) General construction sequence of how the project site will be built, including phases of construction.
  (F) Hydrologic Unit Code (14 Digit) available from the United States Geological Survey (USGS).
  (G) A reduced plat or project site map showing the lot numbers, lot boundaries, and road layout and names. The reduced map must be legible and submitted on a sheet or sheets no larger than eleven (11) inches by seventeen (17) inches for all phases or sections of the project site.
  (H) Identification of any other state or federal water quality permits that are required for construction activities associated with the owner's project site.

(2) Vicinity map depicting the project site location in relationship to recognizable local landmarks, towns, and major roads, such as a USGS topographic quadrangle map or county or municipal road map.

(3) An existing project site layout that must include the following information:
  (A) Location and name of all wetlands, lakes, and water courses on or adjacent to the project site.
  (B) Location of all existing structures on the project site.
  (C) One hundred (100) year floodplains, floodway fringes, and floodways. Please note if none exists.
  (D) Soil map of the predominant soil types, as determined by the United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) Soil Survey, or an equivalent publication, or as determined by a soil scientist. A soil legend must be included with the soil map.
  (E) Identification and delineation of vegetative cover, such as grass, weeds, brush, and trees, on the project site.
  (F) Land use of all adjacent properties.
  (G) Existing topography at a contour interval appropriate to indicate drainage patterns.

(4) Final project site layout, including the following information:
  (A) Location of all proposed site improvements, including roads, utilities, lot delineation and identification, proposed structures, and common areas.
  (B) One hundred (100) year floodplains, floodway fringes, and floodways. Please note if none exists.
  (C) Proposed final topography at a contour interval appropriate to indicate drainage patterns.

(5) A grading plan, including the following information:
  (A) Delineation of all proposed land disturbing activities, including off-site activities that will provide services to the project site.
  (B) Location of all soil stockpiles and borrow areas.
  (C) Information regarding any off-site borrow, stockpile, or disposal areas that are associated with a project site and under the control of the project site owner.
  (D) Existing and proposed topographic information.

(6) A drainage plan, including the following information:
  (A) An estimate of the peak discharge, based on the ten (10) year storm event, of the project site for both preconstruction and postconstruction conditions.
  (B) Location, size, and dimensions of all storm water drainage systems, such as culverts, storm sewers, and conveyance channels.
  (C) Locations where storm water may be directly discharged into ground water, such as abandoned wells or sinkholes. Please note if none exists.
  (D) Locations of specific points where storm water discharge will leave the project site.
  (E) Name of all receiving waters. If the discharge is to a separate municipal storm sewer, identify the name of the municipal operator and the ultimate receiving water.
  (F) Location, size, and dimensions of features, such as permanent retention or detention facilities, including existing or manmade wetlands, used for the purpose of storm water management.

(7) A storm water pollution prevention plan associated with construction activities. The plan must be designed to, at least, meet the requirements of sections 7 and 7.5 of this rule and must include the following:
(A) Location, dimensions, detailed specifications, and construction details of all temporary and permanent storm water quality measures.
(B) Temporary stabilization plans and sequence of implementation.
(C) Permanent stabilization plans and sequence of implementation.
(D) Temporary and permanent stabilization plans shall include the following:
(i) Specifications and application rates for soil amendments and seed mixtures.
(ii) The type and application rate for anchored mulch.
(E) Construction sequence describing the relationship between implementation of storm water quality measures and stages of construction activities.
(F) Self-monitoring program including plan and procedures.
(G) A description of potential pollutant sources associated with the construction activities, that may reasonably be expected to add a significant amount of pollutants to storm water discharges.
(H) Material handling and storage associated with construction activity shall meet the spill prevention and spill response requirements in 327 IAC 2-6.1.
(8) The postconstruction storm water pollution prevention plan. The plan must include the following information:
(A) A description of potential pollutant sources from the proposed land use, that may reasonably be expected to add a significant amount of pollutants to storm water discharges.
(B) Location, dimensions, detailed specifications, and construction details of all postconstruction storm water quality measures.
(C) A description of measures that will be installed to control pollutants in storm water discharges that will occur after construction activities have been completed. Such practices include infiltration of run-off, flow reduction by use of open vegetated swales and natural depressions, buffer strip and riparian zone preservation, filter strip creation, minimization of land disturbance and surface imperviousness, maximization of open space, and storm water retention and detention ponds.
(D) A sequence describing when each postconstruction storm water quality measure will be installed.
(E) Storm water quality measures that will remove or minimize pollutants from storm water run-off.
(F) Storm water quality measures that will be implemented to prevent or minimize adverse impacts to stream and riparian habitat.
(G) A narrative description of the maintenance guidelines for all postconstruction storm water quality measures to facilitate their proper long term function. This narrative description shall be made available to future parties who will assume responsibility for the operation and maintenance of the postconstruction storm water quality measures.

(b) For a single-family residential development consisting of four (4) or fewer lots or a single-family residential strip development where the developer offers for sale or lease without land improvements, and the project is not part of a larger common plan of development or sale, the project site owner shall develop a set of construction plans containing storm water quality measures that achieve the minimum project site requirements specified in section 7 of this rule. The construction plan must include the following:
(1) Project narrative and supporting documents, including the following information:
(A) An index indicating the location, in the construction plans, of all required items in this subsection.
(B) Description of the nature and purpose of the project.
(C) Legal description of the project site. The description should be to the nearest quarter section, township, and range, and include the civil township.
(D) Soil properties, characteristics, limitations, and hazards associated with the project site and the measures that will be integrated into the project to overcome or minimize adverse soil conditions.
(E) Hydrologic Unit Code (14 Digit) available from the United States Geological Survey (USGS).
(F) Identification of any other state or federal permits that are required for construction activities associated with the project site owner's project site.
(2) Vicinity map depicting the project site location in relationship to recognizable local landmarks, towns, and major roads, such as a USGS topographic quadrangle map or county or municipal road map.

(3) A project site layout that must include the following information:
  (A) Location and name of all wetlands, lakes, and water courses on or adjacent to the project site.
  (B) Location of all existing structures on the project site (if applicable).
  (C) One hundred (100) year floodplains, floodway fringes, and floodways. Please note if none exists.
  (D) Soil map of the predominant soil types, as determined by the United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) Soil Survey, or an equivalent publication, or as determined by a soil scientist. A soil legend must be included with the soil map.
  (E) Identification and delineation of vegetative cover, such as grass, weeds, brush, and trees, on the project site.
  (F) Land use of all adjacent properties.
  (G) Existing and proposed topography at a contour interval appropriate to indicate drainage patterns.
  (H) Location of all proposed site improvements, including roads, utilities, lot delineation and identification, and proposed structures.

(4) A storm water pollution prevention plan associated with construction activities. The plan must be designed to, at least, meet the requirements of sections 7 and 7.5 of this rule and must include the following:
  (A) Delineation of all proposed land disturbing activities, including off-site activities that will provide services to the project site.
  (B) Location of all soil stockpiles and borrow areas.
  (C) Location, size, and dimensions of all storm water drainage systems, such as culverts, storm sewers, and conveyance channels.
  (D) Locations where storm water may be directly discharged into ground water, such as abandoned wells or sinkholes. Please note if none exist.
  (E) Locations of specific points where storm water discharge will leave the project site.
  (F) Name of all receiving waters. If the discharge is to a separate municipal storm sewer, identify the name of the municipal operator and the ultimate receiving water.
  (G) Location, dimensions, detailed specifications, and construction details of all temporary and permanent storm water quality measures.
  (H) Temporary stabilization plans and sequence of implementation of storm water quality measures.
  (I) Temporary and permanent stabilization plans shall include the following:
    (i) Specifications and application rates for soil amendments and seed mixtures.
    (ii) The type and application rate for anchored mulch.
  (J) Self-monitoring program plan and procedures.

(c) The SWCD or the DNR-DSC representative or other designated entity may upon finding reasonable cause require modification to the construction plan if it is determined that changes are necessary due to site conditions or project design changes. Revised plans, if requested, must be submitted to the appropriate entity within twenty-one (21) calendar days of a request for a modification.

(Water Pollution Control Board; 327 IAC 15-5-6.5; filed Oct 27, 2003, 10: 15 a.m.: 27 IR 838; errata filed Feb 4, 2004, 1:45 p.m.: 27 IR 2284)

327 IAC 15-5-7 General requirements for storm water quality control
Authority: IC 13-14-8; IC 13-15-1-2; IC 13-15-2; IC 13-18-3; IC 13-18-4
Affected: IC 13-12-3-1; IC 13-18-1

Sec. 7. (a) All storm water quality measures and erosion and sediment controls necessary to comply with this rule must be implemented in accordance with the construction plan and sufficient to satisfy subsection (b).

(b) A project site owner shall, at least, meet the following requirements:
  (1) Sediment-laden water which otherwise would flow from the project site shall be treated by erosion and sediment control measures appropriate to minimize sedimentation.
  (2) Appropriate measures shall be implemented to minimize or eliminate wastes or unused building materials, including garbage, debris, cleaning wastes, wastewater, concrete truck washout, and other substances from being carried from a project site by run-off or wind. Identification of areas where concrete truck washout is permissible must be clearly posted at appropriate areas of the site. Wastes and unused building materials shall be managed and disposed of in accordance with all applicable statutes and regulations.
  (3) A stable construction site access shall be provided at all points of construction traffic ingress and egress to the project site.
  (4) Public or private roadways shall be kept cleared of accumulated sediment that is a result of run-off or tracking. Bulk clearing of sediment shall not include flushing the area with water. Cleared sediment shall be redistributed or disposed of in a manner that is in accordance with all applicable statutes and regulations.

(5) Storm water run-off leaving a project site must be discharged in a manner that is consistent with applicable state or federal law.

(6) The project site owner shall post a notice near the main entrance of the project site. For linear project sites, such a a pipeline or highway, the notice must be placed in a publicly accessible location near the project field office. The notice must be maintained in a legible condition and contain the following information:

(A) Copy of the completed NOI letter and the NPDES permit number, where applicable.

(B) Name, company name, telephone number, e-mail address (if available), and address of the project site owner or a local contact person.

(C) Location of the construction plan if the project site does not have an on-site location to store the plan.

(7) This permit and posting of the notice under subdivision (6) does not provide the public with any right to trespass on a project site for any reason, nor does it require that the project site owner allow members of the public access to the project site.

(8) The storm water pollution prevention plan shall serve as a guideline for storm water quality, but should not be interpreted to be the only basis for implementation of storm water quality measures for a project site. The project site owner is responsible for implementing, in accordance with this rule, all measures necessary to adequately prevent polluted storm water run-off.

(9) The project site owner shall inform all general contractors, construction management firms, grading or excavating contractors, utility contractors, and the contractors that have primary oversight on individual building lots of the terms and conditions of this rule and the conditions and standards of the storm water pollution prevention plan and the schedule for proposed implementation.

(10) Phasing of constII Iction activities shall be used, where possible, to minimize disturbance of large areas.

(11) Appropriate measures shall be planned and installed as part of an erosion and sediment control system.

(12) All storm water quality measures must be designed and installed under the guidance of a trained individual.

(13) Collected run-off leaving a project site must be either discharged directly into a well-defined, stable receiving channel or diffused and released to adjacent property without causing an erosion or pollutant problem to the adjacent property owner.

(14) Drainage channels and swales must be designed and adequately protected so that their final gradients and resultant velocities will not cause erosion in the receiving channel or at the outlet.

(15) Natural features, including wetlands and sinkholes, shall be protected from pollutants associated with storm water run- off.

(16) Unvegetated areas that are scheduled or likely to be left inactive for fifteen (15) days or more must be temporarily or permanently stabilized with measures appropriate for the season to minimize erosion potential. Alternative measures to site stabilization are acceptable if the project site owner or their representative can demonstrate they have implemented erosion and sediment control measures adequate to prevent sediment discharge. Vegetated areas with a density of less than seventy percent (70%) shall be restabilized using appropriate methods to minimize the erosion potential.

(17) During the period of construction activities, all storm water quality measures necessary to meet the requirements of this rule shall be maintained in working order.

(18) A self-monitoring program that includes the following must be implemented:

(A) A trained individual shall perform a written evaluation of the project site:

(i) by the end of the next business day following each measurable storm event; and

(ii) at a minimum of one (1) time per week.

(B) The evaluation must:

address the maintenance of existing storm water quality measures to ensure they are functioning properly; and identify additional measures necessary to remain in compliance with all applicable statutes and rules.

(C) Written evaluation reports must include:

(i) the name of the individual performing the evaluation;

(ii) the date of the evaluation;

(iii) problems identified at the project site; and

(iv) details of corrective actions recommended and completed.

(D) All evaluation reports for the project site must be made available to the inspecting authority within forty-eight (48) hours of a request.

(19) Proper storage and handling of materials, such as fuels or hazardous wastes, and spill prevention and clean-up measures shall be implemented to minimize the potential for pollutants to contaminate surface or ground water or degrade soil quality.

(20) Final stabilization of a project site is achieved when:

(A) all land disturbing activities have been completed and a uniform (for example, evenly distributed, without large bare areas) perennial vegetative cover with a density of seventy percent (70%) has been established or all unpaved areas and areas not covered by permanent structures, or equivalent permanent stabilization measures have been employed; and

(B) construction projects on land used for agricultural purposes are returned to its preconstruction agricultural use or disturbed areas, not previously used for agricultural production, such as filter strips and areas that are not being returned to their preconstruction agricultural use, meet the final stabilization requirements in clause (A).

(Water Pollution Control Board; 327IAC 15-5-7; filed Aug 31, 1992, 5:00 p.m.: 16 IR 24; readopted filed Jan 10, 2001, 3:23 p.m.:24 IR 1518; filed act 27, 2003, 10: 15 a.m.: 27 IR 840; errata filed Feb 4, 2004, 1:45 p.m.: 27 IR 2284)

327 IAC 15-5-7.5 General requirements for individual building lots within a permitted project
Authority: IC 13-14-8; IC 13-15-1-2; IC 13-15-2; IC 13-18-3; IC 13-18-4
Affected: IC 13-12-3-1; IC 13-18-1

Sec. 7.5. (a) All storm water quality measures, including erosion and sediment control, necessary to comply with this rule be implemented in accordance with the plan and sufficient to satisfy subsection (b).

(b) Provisions for erosion and sediment control on individual building lots regulated under the original permit of a project site owner must include the following requirements:

(1) The individual lot operator, whether owning the property or acting as the agent of the property owner, shall be responsible for erosion and sediment control requirements associated with activities on individual lots.

(2) Installation and maintenance of a stable construction site access.

(3) Installation and maintenance of appropriate perimeter erosion and sediment control measures prior to land disturbance. (4) Sediment discharge and tracking from each lot must be minimized throughout the land disturbing activities on the lot until permanent stabilization has been achieved-

(5) Clean-up of sediment that is either tracked or washed onto roads. Bulk clearing of sediment shall not include flushing the area with water. Cleared sediment must be redistributed or disposed of in a manner that is in compliance with all applicable statutes and rules.

(6) Adjacent lots disturbed by an individual lot operator must be repaired and stabilized with temporary or permanent surface stabilization.

(7) For individual residential lots, final stabilization meeting the criteria in section 7 (b)(20) of this rule will be achieved when the individual lot operator:

(A) completes final stabilization; or

(B) has installed appropriate erosion and sediment control measures for an individual lot prior to occupation of the home by the homeowner and has informed the homeowner of the requirement for, and benefits of, final stabilization.

(Water Pollution Control Board; 327 IAC 15-5-7.5; filed Oct 27, 2003, 10:15 a.m.: 27 IR 843)

327 IAC 15-5-8 Project termination
Authority: IC 13-14-8; IC 13-15-1-2; IC 13-15-2; IC 13-18-3; IC 13-18-4
Affected: IC 13-12-3-1; IC 13-18-1

Sec. 8. (a) The project site owner shall plan an orderly and timely termination of the construction activities, including the implementation of storm water quality measures that are to remain on the project site.

(b) The project site owner shall submit a notice of termination (NOT) letter to the commissioner and a copy to the appropriate SWCD or other designated entity in accordance with the following:

(1) Except as provided in subdivision (2), the project site owner shall submit an NOT letter when the following conditions have been met:

(A) All land disturbing activities, including construction on all building lots, have been completed and the entire site has been stabilized.

(B) All temporary erosion and sediment control measures have been removed.

The NOT letter must contain a verified statement that each of the conditions in this subdivision has been met.

(2) The project site owner may submit an NOT letter to obtain early release from compliance with this rule if the following conditions are met:

(A) The remaining, undeveloped acreage does not exceed five (5) acres, with contiguous areas not to exceed one (I) acre.

(B) A map of the project site, clearly identifying all remaining undeveloped lots, is attached to the NOT letter. The map must be accompanied by a list of names and addresses of individual lot owners or individual lot operators of all undeveloped lots.

(C) All public and common improvements, including infrastructure, have been completed and permanently stabilized and have been transferred to the appropriate local entity.

(D) The remaining acreage does not pose a significant threat to the integrity of the infrastructure, adjacent properties, or water quality.

(E) All permanent storm water quality measures have been implemented and are operational.

(c) Following acceptance of the NOT letter and written approval from the department for early release under subsection (b), the project site owner shall notify all current individual lot owners and all subsequent individual lot owners of the remaining undeveloped acreage and acreage with construction activity that they are responsible for complying with sec of this rule. The remaining individual lot owners do not need to submit an NOI letter or NOT letter. The notice must contain a verified statement that each of the conditions in subsection (b) (2) have been met. The notice must also inform the individual lot owners of the requirements to:

(1) install and maintain appropriate measures to prevent sediment from leaving the individual building lot; and

(2) maintain all erosion and sediment control measures that are to remain on-site as part of the construction plan.

(d) The SWCD, DNR-DSC, other entity designated by the department or a regulated MS4 entity, or the department may inspect the project site to evaluate the adequacy of the remaining storm water quality measures and compliance with the NOT letter requirements. If the inspecting entity finds that the project site owner has sufficiently filed an NOT letter, the entity shall forward notification to the department. Upon receipt of the verified NOT letter by the department and receipt of written approval from the department, the project site owner shall no longer be responsible for compliance with this rule.

(e) After a verified NOT letter has been submitted for a project site, maintenance of the remaining storm water quality measures shall be the responsibility of the individual lot owner or occupier of the property.

(Water Pollution Control Board: 327 IAC 15-5-8 filed Aug 31, 1992, 5:00p.m.: 16IR 25; readopted filed Jan 10, 2001, 3:23 p.m.: 24IR 1518; filed Oct 27,2003,10: 15 a.m.: 27 IR 843)

327 IAC 15-5-9 Standard conditions
Authority: IC 13-1-3-4; IC 13-1-3-7; IC 13-7-7; IC 13-7-10-1
Affected: IC 13-1-3; IC 13-7

Sec. 9. The standard conditions for NPDES general permit rules under 327 IAC 15-4 shall apply to this rule.

(Water Pollution Control Board; 327 IAC 15-5-9; filed Aug 31, 1992, 5:00 p.m.: 16 IR 26; readopted filed Jan 10, 2001, 3:23 p.m.: 24 IR 1518)

327 IAC 15-5-10 Inspection and enforcement
Authority: IC 13-13-5-2; IC 13-15-1-2; IC 13-15-2-1; IC 13-18-3-1; IC 13-18-3-2; IC 13-18-3-3; IC 13-18-3-13; IC 13-18-4-1; IC 13-18-4-3
Affected: IC 13-14-10; IC 13-15-7; IC 13-18-4; IC 13-30

Sec. 10. (a) The department or its designated representative may inspect any project site involved in construction activities regulated by this rule at reasonable times. The department or its designated representatives may make recommendations to the project site owner or their representative to install appropriate measures beyond those specified in the storm water pollution prevention plan to achieve compliance.

(b) All persons engaging in construction activities on a project site shall be responsible for complying with the storm water pollution prevention plan and the provisions of this rule.

(c) The department shall investigate potential violations of this rule to determine which person may be responsible for the violation. The department shall, if appropriate, consider public records of ownership, building permits issued by local units of government, and other relevant information, which may include site inspections, storm water pollution prevention plans, notices of intent, and other information related to the specific facts and circumstances of the potential violation. Any person causing or contributing to a violation of any provisions of this rule shall be subject to enforcement and penalty under IC 13-14-10, IC 13-15-7, and IC 13-30.

(d) If remaining storm water quality measures are not properly maintained by the person occupying or owning the property, the department may pursue enforcement against that person for correction of deficiencies under 327 IAC 15-1-4.

(e) Construction plans and supporting documentation associated with the quality assurance plan must be made available to the department or its designated representatives within forty-eight (48) hours of such a request.

(Water Pollution Control Board; 327 IAC 15-5-10; filed Aug 31,1992, 5:00p.m.: 16 IR 26; filed Mar 23, 2000, 4: 15 p.m.: 23 IR 1912; readopted filed Jan 10,2001, 3:23 p.m.: 24 IR 1518; filed Oct 27, 2003, 10: 15 a.m.: 27 IR 844)

327 IAC 15-5-11 Notification of completion (Repealed)

Sec. 11. (Repealed by Water Pollution Control Board; filed Oct 27, 2003, 10:15 a.m.: 27 IR 863)

327 IAC 15-5-12 Duration of coverage

Authority: IC 13-14-8; IC 13-15-1-2; IC 13-15-2; IC 13-18-3; IC 13-18-4

Affected: IC 13-12-3-1; IC 13-18-1

Sec. 12. (a) A permit issued under this rule is granted by the commissioner for a period of five (5) years from the date coverage commences.

(b) Once the five (5) year permit term duration is reached, a general permit issued under this rule will be considered expired, and, as necessary for construction activity continuation, a new NOI letter would need to be submitted in accordance with subsection (c).

(c) To obtain renewal of coverage under this rule, the information required under sections 5 and 6 of this rule must be submitted to the commissioner ninety (90) days prior to the termination of coverage under this NPDES general permit rule, unless the commissioner determines that a later date is acceptable. Coverage under renewal NOI letters will begin on the date of expiration from the previous five (5) year permit term.

(Water Pollution Control Board; 327 IAC 15-5-12; filed Oct 27, 2003, 10; 15 a.m.; 27 IR 844)

Section 2.1.
Ten General Principles of Erosion and Sediment Control

Soil erosion and sedimentation increase dramatically when land is disturbed at a construction site. The resulting detrimental impact on water quality concerns the public as well as natural resource managers. The following general principles should be the basis for a landuser's erosion and sediment control plan as development and construction occurs. The practices in Section 3 are related ultimately to these ten principles.

1. Fit the development to the existing terrain and soil.

* Assess the physical characteristics of the site, including topography, soils, and drainage, to determine how best to develop it with minimal environmental damage.
* Utilize the existing topography to minimize grading.
* Utilize the natural drainage patterns where possible.
* Preserve any existing wetland in accordance with the law.

2. Develop an erosion and sediment control plan before land-disturbing activities begin, then follow it (see Section 2.2).

* If necessary, get professional help in developing such a plan, which should identify the areas where erosion and sedimentation problems are apt to occur on the construction site and specify the measures to reduce those problems. Information is available from local SWCDs, the USDA Soil Conservation Service, IDNR Soil Conservation, and city or county engineering staffs. Some private firms provide the type of assistance needed.
* Obtain all local, state, or federal permits that may apply to the construction activity.
* Make sure that all land-disturbing activities on the site are carried out in accordance with the erosion/sediment control plan.

3. Retain existing vegetation on the construction site wherever possible.

* If existing vegetation must be cleared, retain and protect it until the area must be disturbed.
* Maintain a buffer strip of existing vegetation around the perimeter of the site to reduce off-site erosion and sedimentation.

4. Minimize the extent and duration that bare soil is exposed to erosion by wind and water.

* Use staged clearing and grading (scheduling) to reduce the amount of disturbed area to the absolute minimum needed for immediate construction activities.

5. Keep sediment on the construction site as much as possible.

* Retain sediment from unavoidable erosion on-site by trapping it with sediment basins or by filtering it out of runoff with vegetative or man-made barriers.
* Install any needed sediment traps and basins before construction activities begin.

6. If possible, divert off-site runoff away from disturbed areas.

* Use diversions, perimeter dikes, and waterways to intercept off-site runoff and divert it away from the construction site.
* Install these measures before clearing and grading to reduce the potential for erosion.

7. Minimize the length and steepness of slopes.

* Use stair-step grading, diversions, and sediment barriers to break up long, steep slopes.
* Design measures to slow runoff and allow deposition of sediment.

8. Stabilize disturbed areas as soon as possible.

* Use stabilizing measures, such as seeding temporary or permanent vegetation, sodding, mulching, sediment basins, erosion control blankets, or other protective practices within seven days after the land has been disturbed.
* Consider possible future repair and maintenance needs of the measures selected.

9. Keep velocity of runoff leaving the site low.

* Reduce runoff velocity by maintaining existing vegetative cover, preserving a vegetated buffer

strip around the lower perimeter of the land disturbance, and installing perimeter controls, such as sediment barriers, silt fences, filters, dikes, or sediment basins or traps.

* Depending on local ordinances and site conditions, either (a) discharge concentrated stormwater runoff into a well-defined, adequately protected natural or man-made channel or a pipe large enough to handle the expected maximum storm; or (b) detain the stormwater runoff on-site in a retention/detention facility.

10. Inspect and maintain erosion control measures regularly.

* Assign someone the responsibility for routine, end-of-day inspection/maintenance checks of all erosion and sediment control measures.

* Inspect all measures for damage after each storm event.

* Repair any damaged measure, since it may cause more damage than it prevents if not properly maintained.

* Consider consequences of the failure of a control measure when deciding which one to use. (Failure of a practice may be hazardous or damaging to people and/or property).

* When construction is completed and the area stabilized, remove erosion control measures no longer needed in a manner that minimizes site disturbance, and seed immediately.

Section 2.2
Contents of an Erosion and Sediment Control Plan

The purpose of a development site erosion and sediment control plan (E/SCP) is to establish clearly which control practices are intended to prevent erosion and off-site sedimentation. It serves as a blueprint for the location, installation, and maintenance of these practices. The approved E/SCP, which shows location, design, and construction schedule for all practices, should be part of the general construction contract.

This section, intended as a guide for preparing a construction project erosion/sediment control plan, is divided into three parts:

* *Part 2.2-A* contains basic information that all site planners and plan reviewers should be familiar with, including criteria for plan format and content, and ideas for improved planning effectiveness.

* *Part 2.2-B* outlines and describes a recommended step-by-step procedure for developing an E/SCP from data collection to the finished product. It is written in general terms to be applicable to all types of projects.

* *Part 2.2-C* presents the elements to be included in preparation of both the site plan and the plan narrative

Site planners as well as local plan-approving authorities are urged to become familiar with the contents of this section so that plans will eventually become more standardized and thus more meaningful statewide.

Part 2.2-A. General Guidelines

What an Erosion/Sediment Control Plan Is

It is a document that (a) describes the potential for erosion and sedimentation problems on a construction site and (b) explains and illustrates the measures that will be taken to control those problems.

The E/SCP should be an essential component of the site grading plan. While it's a good idea to include erosion and sediment control standards and specifications in contract documents, the E/SCP itself should be a working document included with the grading plan.

Importance of the Narrative Portion

A narrative is a written statement that explains both the erosion and sediment control decisions made for a particular project and the justification for those decisions.

The narrative is important to the plan reviewing authority because it contains concise information concerning the nature and purpose of the proposed development, existing site conditions, proposed erosion and sedimentation control measures, construction schedules, and other pertinent items not in a typical site plan. The designer must keep in mind that the plan reviewing authority has probably not seen the site and is unfamiliar with the project.

The narrative is also important to the construction site superintendent, who is responsible to implement the plan. It provides a report describing where and when the various erosion and sediment control practices should be installed.

What Constitutes an "Adequate" Plan

An E/SCP must meet the criteria set forth in Part 2.2-B. Its length and complexity depends on the size of the project, severity of site conditions, and the potential for off-site damage.

Obviously, a plan for house construction on a single subdivision lot need not be as complex as one for a shopping center development. Also, a plan for a project undertaken on flat terrain will likely be less complicated than one for a project constructed on sloping terrain where erosion potential is higher. The greatest level of planning and detail should be evident on plans for projects directly adjacent to waterbodies or watercourses, in dense population centers, or on high-value properties where damage may be particularly costly or detrimental.

The step-by-step procedure outlined in Part 2.2-B is recommended for the development of all plans. The site plan and narrative preparation checklists in Part 2.2-C will be especially beneficial to site planners and plan reviewers.

Practice Standards and Specifications

Standards and specifications for the practices used to meet minimum requirements for erosion and sedimentation control are found in Sec. 3. Detail drawings and other design requirements accompany the standards. These practices will be revised and kept current.

Comprehensive Site Planning

Erosion and sediment control planning should be an integral part of the site planning process, not an afterthought. The potential for soil erosion should be a significant consideration when deciding on the layout of buildings, parking lots, roads and other facilities. Erosion and sediment control measures can be minimized if the site design is adapted to existing site conditions and good conservation principles are applied.

Responsibility for Planning/Implementation

The owner or lessee of the land being developed is responsible for plan preparation and implementation. Although that person may designate someone else (e.g., an engineer, architect, contractor) to prepare the plan, he/she retains the ultimate responsibility.

Part 2.2-B. Step-by-Step Plan Development Procedure

The steps in preparing an erosion and sediment control plan include: data collection, data analysis, site plan development, E/SCP formulation, and E/SCP completion. Following is what each step entails.

Step 1. Collecting the Data

Inventory the existing site conditions to gather information that will help you develop the most effective E/SCP. That information, which should be platted on a site map and explained in the narrative portion of the plan, includes:

* **Topography.** Prepare a topographic map of the site to show the existing contour elevations at intervals of two feet.

* **Drainage patterns.** On the topographic map, locate and clearly mark all existing drainage swales, watershed boundaries, unstable (eroding) stream reaches, and known flood marks.

* **Soils.** Determine and show on a site map or overlay the major soils type(s) associated with the site. Indicate critical or highly erodible soils that should be left undisturbed; also note critical areas, such as steep slopes, eroding areas, rock outcroppings, and seepage zones; and identify any unique or noteworthy landscape features to be protected when they appear on the site.

Soils information can be obtained from a detailed county soil survey (available at your local SCS/SWCD office) or from a private soil consultant. Such information should be platted directly onto a site map or an overlay of the same scale for ease of interpretation.

* **Ground cover.** On a site map or overlay, show existing vegetation, including tree clusters, grassy areas, and unique vegetation. Also indicate denuded or exposed soil areas.

* **Adjacent areas.** On the topographic map, delineate areas adjacent to the site, including such features as streams, roads, houses, or other buildings, and wooded areas. Streams and ponds that will receive runoff from the site should be surveyed to determine their carrying capacity and sensitivity to sedimentation and flooding.

Step 2. Analyzing the Data

When the data collected in Step 1 are considered together, a picture of the site's potentials and limitations will begin to emerge. You should be able to determine those areas that may have critical erosion hazards. The following are some important points to consider in site analysis:

* **Topography.** The primary topographic cosiderations are slope steepness and slope length.

When the percent of slope has been determined, outline the areas of similar steepness. Slope gradients can be grouped into three general ranges of soil erodibility:

0-6%--Low to moderate erosion hazard
6-12%--Moderate to high erosion hazard
Over 12%--Severe erosion hazard

Within these slope gradient ranges, the greater the slope length, the greater the erosion hazard. Therefore, in determining potential critical areas, you should be aware of excessively long slopes. As a general rule, the erosion hazard will become critical if slope lengths exceed the following values:

0-6%--200 feet
6-12%--100 feet
Over 12%--50 feet

*** Natural drainage.** Natural drainage patterns exist on the land and include overland flow swales and depressions and natural watercourses. Identify those critical areas where water flow may concentrate. Where possible, use natural drainageways to convey runoff from the site.

Man-made ditches and waterways will contribute to erosion problems if not properly stabilized. Take care to ensure that increased runoff from the site will not erode or flood the existing natural drainage system. Sites for stormwater detention should be determined at this point in the planning process.

*** Soils.** Soils should be considered when laying out building lots, roads, storm sewers, etc., Conditions such as depth to bedrock, depth to seasonal watertable, permeability, shrink-swell potential, texture, and erodibility will exert a strong influence on land development decisions.

*** Ground cover.** Ground cover is the most important factor in terms of preventing erosion; therefore, save any existing cover, if possible. Trees and other vegetation protect the soil as well as beautify the site after construction.

If the existing vegetation cannot be saved, consider staging construction or mulching and temporary seeding. Staging of construction involves stabilizing one part of the site before disturbing another, which minimizes the time soil is exposed. Mulching and temporary seeding involve mulching and seeding areas that would otherwise lie exposed for long periods of time, thus reducing the erosion hazard.

*** Adjacent areas.** An analysis of adjacent properties should focus on areas downslope from the construction project. Of major concern should be watercourses and waterbodies that will receive direct runoff from the site. You must consider their potential for sediment pollution and for downstream channel erosion due to increased volume, velocity, and stormwater flow from the site. Also analyze the potential for sediment deposition due to sheet and rill erosion so that appropriate sediment trapping can be planned.

Step 3. Developing the Site Plan

After analyzing the site and mapping those areas to be preserved from development, site planning can begin. Good site planning and development standards do much to avoid increased runoff, erosion, and sedimentation problems.

Land development has an array of impacts on runoff and water quality. Listed below are some of those impacts:

* *Increased peak discharges during development (between two to five times that of pre-development conditions).*

* *Increased volume of runoff (often as much as 50% more than pre-development conditions.)*

* *Decreased time for runoff to reach streams (often by 50% or more). This is especially true if extensive drainage "improvements" are made as part of the development.*

* *Increased frequency and severity of downstream flooding.*

* *Reduced streamflow during dry periods, thus magnifying water quality problems.*

* *Greater runoff velocities during storms, thus increasing erosion/sedimentation problems.*

* *Less infiltration, thus reducing groundwater recharge.*

The following goals can serve as a guide to site planning. If met, the adverse impacts on runoff and water quality could be markedly reduced.

A. Reproduce pre-development hydrological conditions. The focus of stormwater management is on minimizing the frequency and severity of flooding, chiefly by reducing peak discharges from new development. To accomplish this means generating site design concepts that minimize use of pavements and impervious surfaces, designing for infiltration opportunities to restore pre-development runoff volumes, and using vegetated swales as much as possible to try to match pre-development runoff velocities.

B. Confine development and construction activities to the least critical areas. Use the slope, soil, and vegetation data collected and analyzed in Steps 1 and 2 to map those areas that should be entirely avoided by development (e.g., steep and long slopes, areas of erodible soils, fragile vegetation, etc.). Use such areas instead as open space or as natural areas to enhance the development. "Cluster development" can be used to facilitate avoidance of sensitive areas.

C. Fit development to terrain. Choose road patterns to provide access schemes that match the landform. For example, in rolling, dissected terrain, use branching local streets in short loops and cul-de-sacs from collector streets. This results in a road pattern that resembles the branched patterns of ridgelines and drainageways in the natural landscape, thus facilitating a development that "fits" the landform and minimizes disruption of existing grades and natural drainage.

D. Preserve and utilize the natural drainage system.

The following general procedure is recommended for site planning for erosion and sediment control:

A. *Determine unit-lot relationships to match site conditions and meet hydrologic objectives.* The unit-lot relationship is a facet of site planning too often accepted as a "given," even though it offers good opportunity to reduce runoff peaks, volumes, and velocities.

B. *Develop prototype clusters of lots on paper for each unit type and site situation before addressing lot layout on the total site.* This avoids many of the pitfalls encountered in siting roads first then the lots. By working out in advance the objectives and problems of lot-street relationships, you can more readily see opportunities to capitalize on the physical characteristics of the site to minimize impact and maximize amenity.

C. *Begin planning the subdivision by working over a base map of the site on which the areas to be avoided are clearly delineated and shaded in.* Apply prototype clusters to the plan, bending or truncating them as needed so that drainageways and preserved lands fall along backlot lines between unit clusters as much as possible to provide buffer spaces between them. Set and check trial grades for both roads and lot cluster to determine the area disturbed by earthwork operations. Adjust layout and slopes as needed to minimize disturbed areas without compromising existing drainage patterns.

Step 4. Formulating the E/SCP

When the layout of the site has been decided upon, the E/SCP can then be formulated. It must contain sufficient information to describe the site development and the system intended to control erosion and prevent off-site damage from sedimentation. The following general procedure is recommended for erosion and sediment control planning:

A. Determine limits of clearing and grading. Decide exactly which areas must be disturbed in order to accommodate the proposed construction, paying special attention to the critical areas that must not be disturbed.

B. Divide the site into drainage areas. Determine how runoff will travel over the site to identify the various drainage areas, then consider how erosion and sediment action can be controlled in each small area before looking at the entire site. Remember, it's easier to control erosion than to contend with sediment after it has been carried downstream.

C. Select the appropriate erosion and sediment control practices. These can be divided into three broad categories--vegetative controls, structural controls, and management measures.

Vegetative controls (see Sec. 3) are the first line of defense against erosion. The best way to protect the soil surface is to preserve the existing ground cover. Where land disturbance is necessary, seeding and mulching can be used to stabilize the area.

Structural controls (see Sec. 3), although generally more costly, are often necessary on disturbed areas that cannot be protected with vegetation. They are usually the second or third line of defense to capture sediment before leaving the site.

Management measures include: (a) staging construction on large projects so that one area can be stabilized before another is disturbed; (b) delegating responsibility for implementing the E/SCP to one individual, preferably the job superintendent or foreman; (c) ensuring that workers understand the major provisions of the E/SCP; (d) physically marking off limits of land disturbance on the site with tape, signs, etc. so workers can see areas to be protected; and (e) developing and carrying out a regular maintenance schedule for erosion and sediment control practices.

D. Plan for stormwater management. Where increased runoff will cause the carrying capacity of a receiving channel to be exceeded, select appropriate stormwater management measures.

Step 5. Completing the E/SCP

With the necessary planning work done (Steps 1-4), the final step is to consolidate this information into a specific E/SCP for the project. It consists of two parts--a narrative and a site plan.

The narrative explains site problems and their solutions with all necessary documentation. The site plan is one or a series of maps and drawings that "show" the information explained in the narrative, including all applicable construction schedules, location of erosion and sediment control measures, and construction drawings and specifications for the project.

Part 2.2-C. Elements to Include in the Site Plan and Plan Narrative

Following are the items that should be included on the site plan map(s) and in a narrative accompanying the site plan. They provide a quick reference to the major elements included in the erosion and sediment control plan.

All of these items must be considered for every plan, regardless of the extent of earth disturbance. Keep in mind, however, that factors addressed in one plan do not necessaily have to be addressed in another. For example, the plan needed for a small, single residential lot without any upstream contributing drainage may not have to list the staging of earth-moving activities if perimeter controls are in place.

Elements in the Site Plan

A. **Location map with north indicated.** Provide a small map locating the site in relation to the direction north and to the surrounding areas.

** The location map may be an insert on the topographic map or a separate sheet in the narrative report. A copy of part of a 7½-min. USGS quadrangle map is recommended for this purpose; if used, include the name of the USGS map on the location map.*

** The map must include the location of the project with respect to roadways, municipalities, streams, watercourses, existing structures, and other identifiable landmarks.*

B. **Scale.** Indicate scale, using a graduated line, which represents the drawn dimensions in relation to actual size of the project site, usually in number of feet per inch.

** The scale of the map must be large enough to clearly depict the topographic features, and the contours must be at an interval that will adequately describe the topography of the site. Scales of 1 in. = 100 ft. or less, with 2-ft. maximum contour intervals, are recommended.*

C. **Benchmark.** Show an established elevation affixed to a permanent object that can be used to check grade.

D. **Plan drawings.** Provide drawings of the project site that include:

1. **Map(s) of existing site conditions.**

   a. *Contours.* Show existing contours of the site. They must extend a minimum of 200 ft. beyond property boundaries and should be on 2-ft. intervals.

   b. *Vegetation.* Indicate existing tree lines, grassy areas, or unique vegetation.

   c. *Soils.* Show boundaries of the different soil types, as delineated in the SCS detailed county soil survey or as determined by a certified professional soil scientist.

   d. *Property boundaries and lot lines.* Show boundaries of the property, lot lines, section lines, and adjacent plats.

   e. *Drainage.* Indicate dividing lines, approximate dimensions or size, and the direction of flow for the different drainage areas. The map must include enough of the surrounding area so that streams, channels, ditches, and other watercourses receiving runoff from the project site can be identified and evaluated for resistance to erosion. If runoff from upstream watershed areas is included in the stormwater calculations, such drainage areas must also be shown. Also show any lakes, ponds, wetlands, 100-yr. floodplains, floodway fringes, and floodways.

   f. *Groundwater recharge areas.* Indicate areas of potential groundwater recharge.

   g. *Critical erosion areas.* Indicate areas with potentially serious erosion problems.

   h. *Physical structures and infrastructures.* Show locations and approximate dimensions of utilities, structures, roads, highways, etc.

2. **Map of final site conditions.** (On same scale as the existing site conditions map.)

   a. *Contours.* Show changes to the existing contours.

   b. *Elevation and grade.* Show elevation of lot corners; grade of streets and parking lots; natural high level (NHL) and high water level (HWL) of ponds, wetlands, and lakes; elevation of storm sewer inlets and outlets; and elevations of first floor of proposed structures.

   c. *Infrastructures.* Indicate locations of roads, paved areas, and utilities in the proposed development area.

3. **Site plan construction map.** (The following also apply to all off-site disposal or borrow areas that are part of the project.)

   a. *Limit of clearing and grading.* Show locations and approximate dimensions of all areas to be cleared and graded.

b. *Location of soil stockpiles.* Show areas where soil stockpiles may be located.

c. *Location of erosion and sediment control practices.* Indicate locations of all erosion and sediment control and stormwater management practices used on the site.

4. **Detailed drawing of practices.** (Provide a drawing of each erosion/sediment control and stormwater management practice to be used on the site, including construction details and specifications.)

E. **Construction schedule.** Provide a schedule of anticipated starting and completion dates for each land-disturbing activity and practice installation (i.e., dates disturbed and stabilized).

F. **Plan preparer and responsible individual.** Include the signatures, addresses, and telephone numbers of the person or agency that prepared the E/SCP and the one responsible for implementation and maintenance of practices.

Elements of the Plan Narrative

A. **Project description.** Describe the nature and purpose of each land-disturbing activity and the amount of grading involved.

B. **Phasing of construction.** Describe the proposed stages of grading, utilities, and building construction from initial site clearing through final stabilization. Include anticipated beginning and completion dates for each land-disturbing activity, schedule of installation of facilities and erosion control measures as they relate to the various phases of earth-moving activities, and time of year they will occur.

C. **Existing site conditions.** Describe the existing topography, vegetation, and drainage.

D. **Adjacent areas.** Describe neighboring areas (streams, lakes, residential areas, roads, etc., that might be affected by the land disturbance.

E. **Soils.** Describe the soils on the site, including soil name, mapping unit name, structure, permeability, depth, texture, and suitability for intended use. This information is available in SCS detailed county soil survey reports available from local SCS/SWCD offices.

F. **Critical areas.** Describe areas on the site that have potential for serious erosion problems.

G. **Erosion/sediment control measures.** Describe the type, purpose, and design computation of each practice that will be used to control erosion and sedimentation on the site. Also provide design information for watercourse channel stabilization, including drainage area, anticipated flow rate, velocity, and proposed stabilization methods, such as vegetation, rock lining, etc.

H. **Permanent stabilization.** Describe type, purpose, specifications, and installation date of each permanent stabilization practice to be installed after construction is completed.

I. **Stormwater management considerations.** If development of the site could increase peak rates of runoff or result in flooding or channel degradation downstream, consider stormwater control structures on the site.

** Diversion terraces and other channels must be designed to convey the discharge from their contributing drainage areas. Of the various methods for computing peak discharges, the two most popular are the USDA Technical Release 55 (preferred) and the Rational. To obtain TR-55, Urban Hydrology for Small Watersheds, as a publication alone or with a computer program, contact the National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, VA. 22161 (phone 703-487-4650).*

** The narrative portion of an E/SCP must contain the computations used to determine design capacities for the various practices included in the plan. The computation methods must be clearly identified and all factors used in the computations clearly tabulated. Also included must be (1) an analysis of the impact that runoff from the project site will have on the downstream watercourses' resistance to erosion and (2) design computations of any protective measures for those downstream watercourses.*

J. **Maintenance.** Provide a schedule of regular inspections and the repair of erosion and sediment control structures.

** The maintenance narrative includes: a schedule of inspection of the control measure (after each storm event as well as on a weekly basis, as a minimum); type of maintenance (e.g., cleanout, repair, replacement, regrading, reseeding, etc.), and site and method of disposal of materials removed from the control measure or project area. If sediment basins are installed, the elevation corresponding to top of sediment storage level must be specified as well as the means of identifying this elevation.*

K. **Calculations.** Show any calculations made for the design of such items as sediment basins, diversions, waterways, and runoff and stormwater detention basins.

Section 2.3
Developing and Using a Construction Sequence Schedule to Enhance Erosion and Sediment Control

A construction sequence schedule is a chronological listing of construction activities to be performed and the accompanying erosion and sediment control practices to be installed ahead of or concurrent to these activities. The purpose of such a schedule is to minimize on-site erosion and off-site sedimentation during and after construction. It also helps make field personnel, such as on-site construction managers and foremen, more aware of the possibilities of erosion prevention through construction management.

A construction sequence schedule is created by (1) listing those land-disturbing activities needed to complete the project, (2) listing the practices needed to control erosion and sedimentation on the site, then (3) combining the two lists into a logical sequence. Such a schedule helps establish the timetable for installing the erosion/sediment control practices and shows their likely compatibility with the general construction schedule.

Following (and summarized in *Exhibit 2.3-A*) is the general sequence of development site construction activities and erosion/sediment control practices that should accompany them. These activities will not always occur consecutively; and any schedule developed will likely be affected by weather and other unpredictable factors. Nevertheless, a proposed construction sequence should be formulated and included in your erosion/sediment control plan, as well as the overall construction plans for the entire project.

Suggested Sequence of Construction Site Erosion and Sediment Control Measures

* Call the Indiana Underground Plant Protection Systems, Inc. ("Holey Moley") at 1-800-382-5544 to check the location of any existing utilities. They should be notified two working days before construction takes place.

* Before opening up the site, first evaluate, mark, and protect important trees and associated root zones, unique areas to be preserved (i.e. wetlands), or existing vegetation suitable for use as filter strips (especially in perimeter areas).

* For sites utilizing on-site waste disposal that will not be served by sanitary sewers, protect areas designated as septic tank absorption fields with temporary fencing to prohibit accidental soil disturbing activities (i.e., vehicular traffic compaction, excavating, or filling).

* Before clearing and grading, install sediment basins or traps around the perimeter of the site and diversions above the site. The intent is to direct water from undisturbed areas away *from* the sediment traps while conveying sediment-laden runoff from disturbed areas *to* the traps.

* Also before clearing and grading, install the main runoff conveyance system with inlet and outlet protection devices to convey storm runoff through the site without creating gullies and to prevent damage to the receiving waters.

* As soon as the storm drain system is functional, install drain inlet protections, which trap sediment on-site in shallow pools while allowing high water flows to enter the system.

* Install streambank stabilization practices (including necessary stream crossings) independently and ahead of other construction activities. The reason is that increased storm runoff resulting from subsequent site clearing and construction makes streambank stabilization work more difficult and costly.

Note: State or federal permits may be needed for construction in floodways, streams, near lakes, or wetlands from the following agencies in addition to possible approval of county or local government agencies. When in doubt, contact local authorities as well as the following:

1. For construction involving (a) a stream with more than 1 sq. mi. of drainage above the project site, (b) the floodway of a river or stream, (c) natural lakes, or (d) ditches or drains within 1/2 mi. of a freshwater lake, contact: *Division of Water, IDNR, 402 W. Washington St., W-264, Indianapolis, IN 46204 (ph: 317-232-5660).*

2. When construction involves large streams (under jurisdiction of Section 10 of the Federal Rivers and Harbors Act) or wetlands (under the jurisdiction of Section 404 of the Federal Clean Water Act), contact: *U.S. Army Corps of Engineers, Regulatory Functions Branch, P.O. Box 1027, Detroit, MI 48231-1027 (ph: 313-226-6828)* <u>if in the northern 1/3 of Indiana</u>, OR *U.S. Army Corps of Engineers, Attn: CEOR-F, P.O. Box 59, Louisville, KY 40201-0059 (ph: 502-582-5607)* <u>if in the southern 2/3 of Indiana</u>.

* Once erosion and sediment control measures are in place, begin land clearing followed immediately by grading. Do not leave large areas unprotected for more than 7 days. Adjoining areas planned for development should be left undisturbed as long as possible to serve as natural buffer zones.

* As grading is done, install additional traps, silt fences, slope drains, temporary diversions, and other runoff control measures at appropriate locations to keep sediment contained on-site.

* Immediately after grading, apply surface stabilization practices on all graded areas, using permanent measures in accordance with your erosion/sediment control plan. However, if weather delays permanent stabilization, temporary seeding and/or mulching may be necessary as a stopgap measure. Also stabilize (using temporary seeding/mulching or other suitable means) any disturbed area where active construction will not take place for 30 working days.

* Coordinate building construction with other development activities so that all work can take place in an orderly manner and on schedule.

* For housing development construction, use perimeter sediment barriers and gravel entrances to keep sediment from leaving individual homesites and affecting the road surfaces, storm sewers, and established grassed waterways.

* After construction and final grading, landscape and permanently stabilize all disturbed sites, including borrow and disposal areas. Also remove temporary runoff control structures and any unstable sediment around them, and vegetate those areas.

Additional Construction
Sequence Schedule Suggestions

1. Assign an on-site person with the daily responsibility and authority to ensure that erosion/sediment control practices are installed according to the sequence schedule.

2. Determine to follow the planned sequence throughout the development period.

3. If construction activities must be changed, amend the schedule to reflect those changes.

4. Be prepared to use construction techniques that are not scheduled but, because of timeliness, can greatly reduce erosion potential at a site (i.e., re-shaping earthen fills periodically to prevent overflows or constructing temporary diversions ahead of anticipated storms).

Exhibit 2-A. Considerations in Construction Sequence Scheduling.

Construction phase (specific activities or erosion control practices)*	Construction schedule considerations
Pre-construction actions (Evaluation/protection of important site characteristics)	Before construction, evaluate, mark, and protect important trees and associated rooting zones, unique areas (e.g., wetlands) to be preserved, on-site septic system absorption fields, and vegetation suitable for filter strips, especially in perimeter areas.
Construction access (Construction entrances, construction routes, equipment parking areas)	Stabilize bare areas immediately with gravel and temporary vegetation as work takes place.
Sediment barriers and traps (Basin traps, silt fences, outlet protections)	Install principal basins after construction site is assessed. Install additional traps and barriers as needed during grading.
Runoff control (Diversions, perimeter dikes, water bars, outlet protection)	Install practices after principal sediment traps installed but before land grading. Install additional runoff control measures during grading as needed.
Runoff conveyance system (Stabilized streambanks, storm drains, inlet and outlet protections, channels)	Where necessary, stabilize streambanks as early as possible. Install principal conveyance system with runoff control measures. Install remainder of system after grading.
Land clearing and grading (Cutting/filling/grading, drains, sediment traps, barriers, diversions, surface roughening)	Begin major clearing and grading after installing the key sediment and runoff measures. Clear borrow and disposal areas as needed. Install additional control measures as grading progresses.
Surface stabilization (Temporary and permanent seeding, mulching, sodding, riprap)	Apply temporary or permanent stabilization measures immediately on all disturbed areas where work is delayed or completed.
Building construction (Buildings, utilities, paving)	Install necessary erosion and sediment control practices as work takes place.
Landscaping and final stabilization (Topsoiling, trees and shrubs, permanent seeding, mulching, sodding, riprap)	Stabilize all open areas, including borrow and spoil areas. Remove temporary control measures and stabilize.

* Maintenance--(1) inspect practices at least once a week, and (2) make repairs immediately after periods of rainfall.

Sub-Section 3.0

SITE PREPARATION

3.01 Temporary Gravel Construction Entrance/Exit

3.02 Topsoil (Salvage and Utilization)

3.03 Surface Roughening

Practice 3.01
Temporary Gravel Construction Entrance/Exit Pad

Purpose
(Exhibit 3.01-A)

* To provide a stable entrance/exit condition from the construction site.
* To keep mud and sediment off public roads.

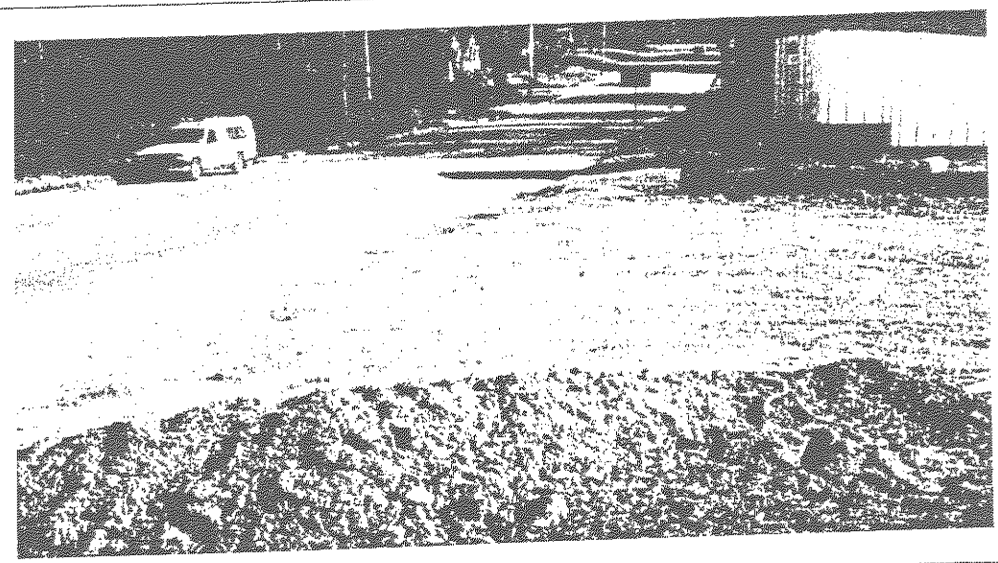


Exhibit 3.01-A. Temporary gravel construction entrance/exit pad helps keep sediment off public roads.

Requirements
(Exhibit 3.01-B)

Material: 2-3 in. washed stone (INDOT CA No. 2) over a stable foundation.
Thickness: 6 in. minimum
Width: 12 ft. minimum or full width of entrance/exit roadway, whichever is greater.
Length: 50 ft. minimum. The length can be shorter for small sites such as for an individual home.
Washing facility (optional): Level area with 3 in. washed stone minimum or a commercial rack, and waste water diverted to a sediment trap or basin (Practice 3.72).
Geotextile fabric underliner: May be used under wet conditions or for soils within a high seasonal water table to provide greater bearing strength.

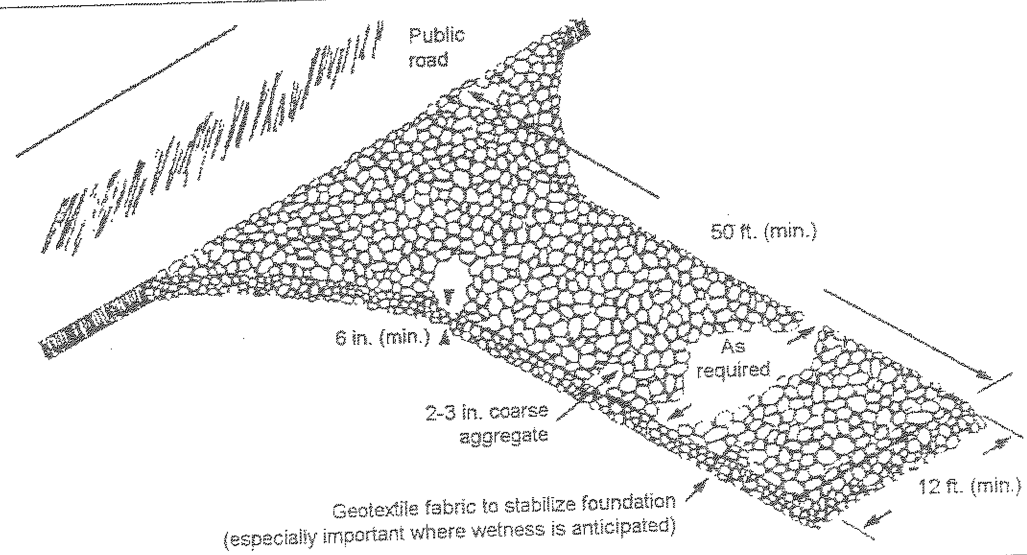


Exhibit 3.01-B. Plan of a temporary gravel construction entrance/exit pad.

Installation
(Exhibit 3.01-C)

1. Avoid locating on steep slopes or at curves in public roads.
2. Remove all vegetation and other objectionable material from the foundation area, and grade and crown for positive drainage.
3. If slope towards the road exceeds 2%, construct a 6-8 in.-high water bar (ridge) with 3:1 side slopes across the foundation area about 15 ft. from the entrance to divert runoff away from the road (Practice 3.24) (see *Exhibit 3.01-C*).
4. Install pipe under the pad if needed to maintain proper public road drainage.
5. If wet conditions are anticipated, place geotextile fabric on the graded foundation to improve stability.
6. Place stone to dimensions and grade shown in the erosion/sediment control plan, leaving the surface smooth and sloped for drainage.
7. Divert all surface runoff and drainage from the stone pad to a sediment trap or basin.

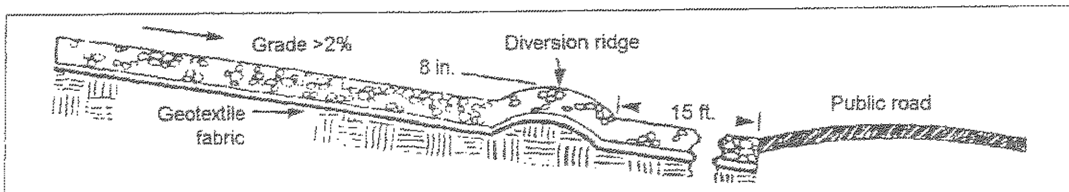


Exhibit 3.01-C. Temporary construction entrance/exit pad with diversion ridge where grade exceeds 2%.

Maintenance

* Inspect entrance pad and sediment disposal area weekly and after storm events or heavy use.
* Reshape pad as needed for drainage and runoff control.
* Topdress with clean stone as needed.
* Immediately remove mud and sediment tracked or washed onto public roads by brushing or sweeping. Flushing should only be used if the water is conveyed into a sediment trap or basin.
* Repair any broken road pavement immediately.

Common concerns
(Exhibit 3.01-D)

Inadequate runoff control—results in sediment washing onto road (see *Exhibit 3.01-D*).
Stone too small, pad too thin, or geotextile fabric absent—results in ruts and a muddy condition as stone is pressed into the soil: add more stone.
Pad too short for heavy construction traffic—extend the pad beyond the 50-ft. length as needed.
Pad not flared sufficiently at road entrance—results in mud being tracked onto the road and possible damage to the road edge: widen stone entrance and repair road damage.
Unstable foundation—use geotextile fabric under the pad and/or improve foundation drainage.

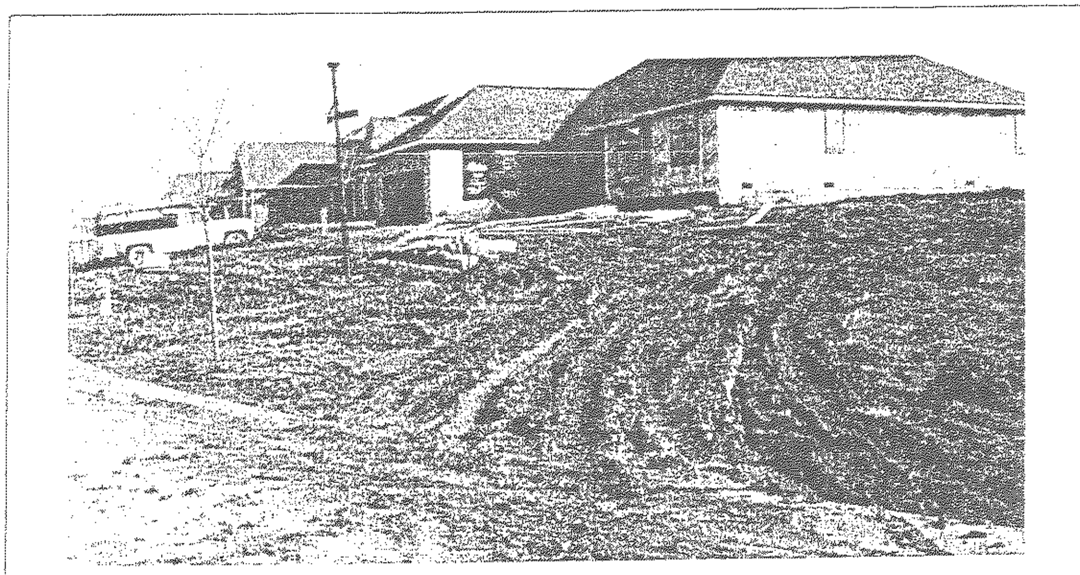


Exhibit 3.01-D. Inadequate runoff control allows sediment to be tracked or washed onto the road and into storm sewers.

Practice 3.02
Topsoil (Salvage and Utilization)

Purpose
(Exhibit 3.02-A)

* To provide a suitable soil medium for vegetative growth on areas with poor moisture, low nutrient levels, undesirable pH, and/or the presence of other materials that would inhibit establishment of vegetation.

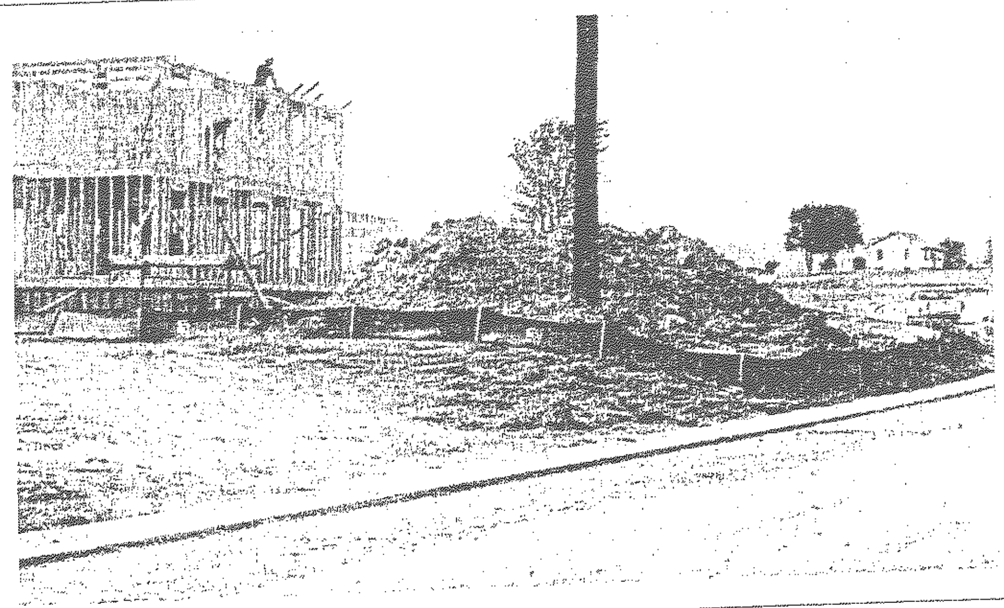


Exhibit 3.02-A. A silt fence barrier retains the stored topsoil at this homesite.

Requirements

Material: Normally darker, friable, and loamy surface soil taken from areas that have not been stripped or graded.
Storage area: Kept free of stumps, rock, and construction debris.
Preferred site conditions: Flatter than 2:1 and free of noxious weeds.
Removal/storage/re-spreading plan: Needed to assure these operations will be compatible with overall construction activities at the site.

Application
(Exhibit 3.02-B)

SALVAGING AND STOCKPILING TOPSOIL:

1. Determine depth and suitability of topsoil at the site. (For help, contact your local SWCD office to obtain a county soil survey report or consult with a soil scientist.)
2. Prior to stripping topsoil, install any site-specific downslope practices needed to control runoff and sedimentation.
3. Remove the soil material no deeper than what the county soil survey describes as "surface soil" (i.e., A or Ap horizon).
4. Stockpile the material in accessible locations that neither interfere with other construction activities nor block natural drainage; and install silt fences, straw bales, or other barriers to trap sediment (see *Exhibit 3.02-B*). (Several small piles around the construction site are usually more efficient and easier to contain than one large pile.)
5. If soil is stockpiled for more than 6 mo., it should be temporarily seeded or covered with a tarp or surrounded by a sediment barrier.

SPREADING TOPSOIL:

1. Prior to applying topsoil, grade the subsoil and roughen the top 3-4 in. by disking. This helps the topsoil bond with the subsoil.
2. Do not apply topsoil when the site is wet, muddy, or frozen, because it makes spreading difficult, inhibits bonding, and can cause compaction problems.

3. Apply topsoil evenly to a depth of at least 4 in. (8-12 in. if the underlying material is bedrock, loose sand, rock fragments gravel, or other unsuitable soil material); then compact slightly to improve contact with the subsoil.
4. After spreading, grade and stabilize.

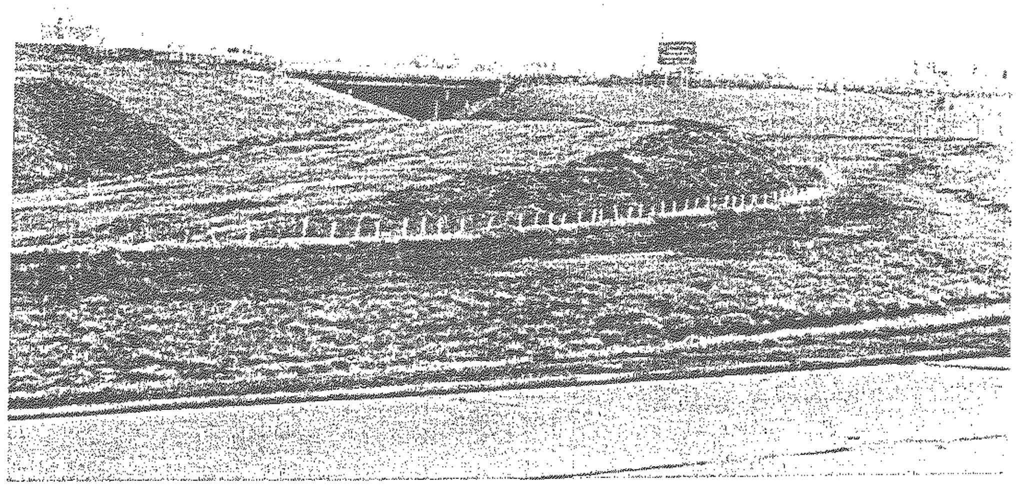


Exhibit 3.02-B. Here a straw bale barrier is being used to retain the topsoil.

Maintenance

* Inspect newly topsoiled areas frequently until vegetation is established.
* Repair eroded or damaged areas and revegetate.

Common concerns

Topsoil spread when conditions were too wet—results in severe compaction.

Topsoil mixed with too much unsuitable subsoil material—results in poor vegetation establishment.

Topsoil contaminated with soil sterilants or chemicals—results in poor or no vegetation establishment.

Topsoil not adequately incorporated or bonded with the subsoil—results in poor vegetation establishment and soil slippage on sloping areas.

Topsoiled areas not protected—results in excessive erosion.

Practice 3.03
Surface Roughening

Purpose
(Exhibit 3.03-A)

* To aid in the establishment of vegetative cover from seed.
* To reduce runoff velocity and increase infiltration.
* To reduce erosion and provide for sediment trapping.

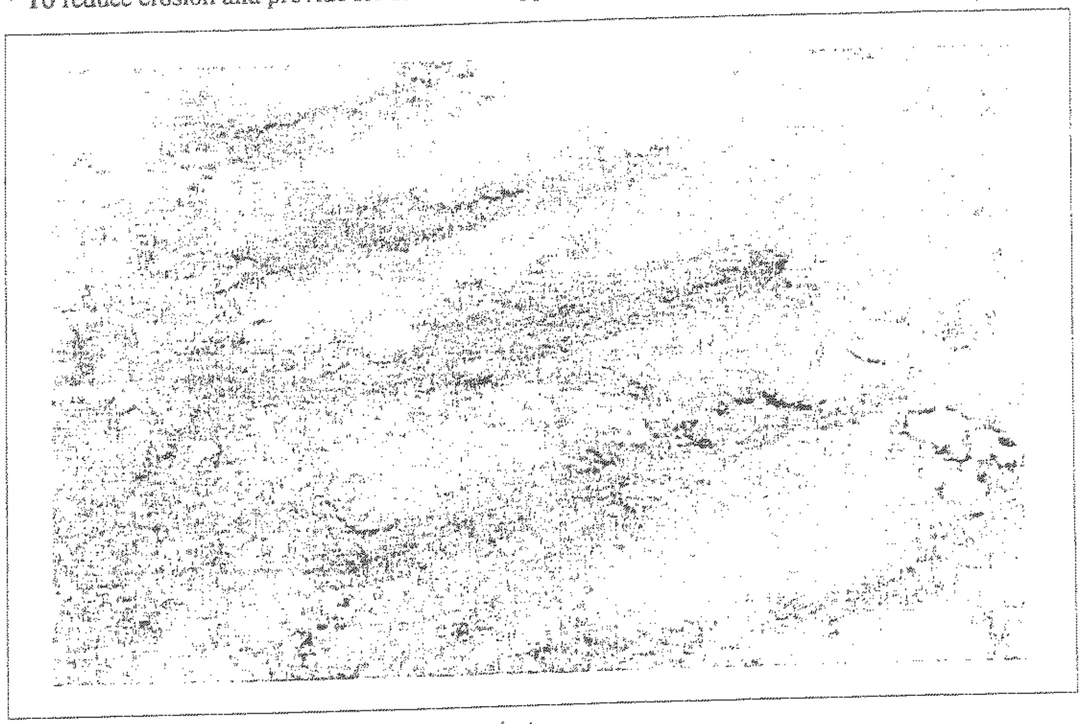


Exhibit 3.03-A. Surface roughening by bulldozer cleats.

Where used

On all slopes that are to be stabilized with vegetation.

On graded areas that are not stabilized immediately, in order to reduce runoff velocity until seeding takes place. (NOTE: Although appearing finished, graded areas with smooth, hard surfaces are difficult places on which to establish vegetation.)

Installation
(Exhibits 3.03-B, C, D, and E)

ROUGHENING CUT SLOPES NOT TO BE MOWED:

1. Stair-step grade or groove any cut slopes having a gradient steeper than 3:1. (Use stair-step grading on any erodible material soft enough to be ripped with a bulldozer, particularly on slopes consisting of soft rock with some subsoil.)
2. To stair-step, (a) make the vertical cut distance less than the horizontal distance, (b) make each vertical cut no more than 2 ft. in soft material or 3 ft. in rocky material, and (c) slightly slope the horizontal position of each "step" in toward the vertical wall (see *Exhibit 3.03-B*).
3. To groove, (a) use implements that can be safely operated on the slope (e.g., disk, tiller, spring harrow, front-end bucket loader teeth) to create a series of ridges and depressions that run across the slope on the contour, and (b) make grooves at least 3 in. deep and no more than 15 in. apart (see *Exhibit 3.03-C*).

ROUGHENING FILL SLOPES NOT TO BE MOWED (see *Exhibit 3.03-D*):

1. Place fill slopes having a gradient steeper than 3:1 in 6-8 in. lifts and compact each lift.
2. Cover the face of the slope with 4-6 in. of loose, uncompacted fill.
3. If necessary, use grooving as described above to roughen the face of the slope, but do not blade or scrape.

ROUGHENING SLOPES TO BE MOWED:

1. Make slopes to be mowed no steeper than 3:1.

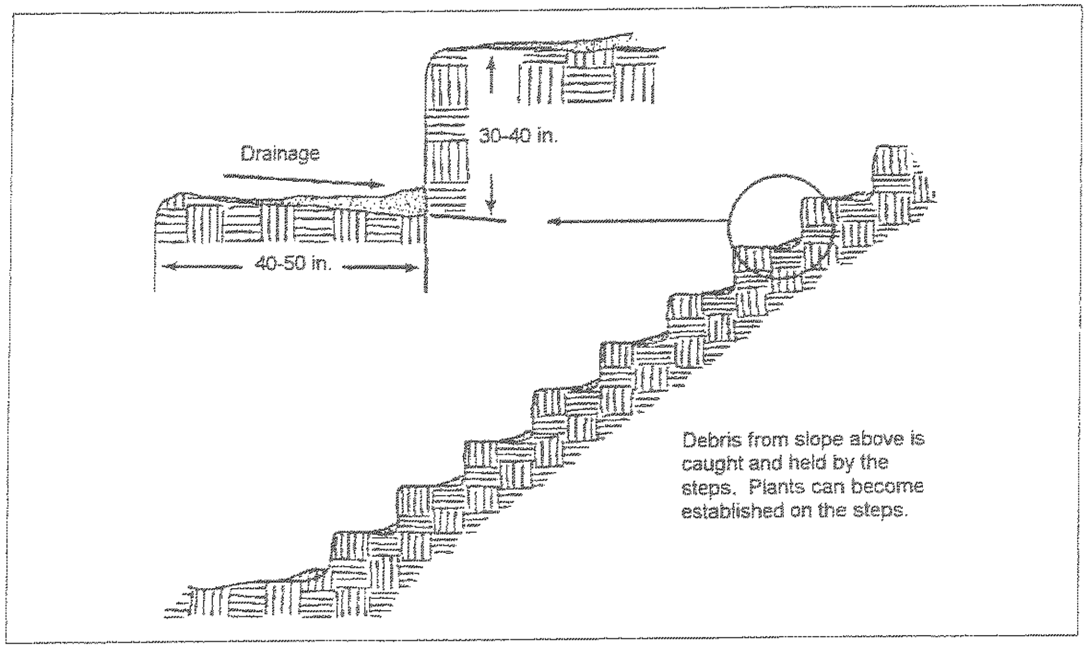


Exhibit 3.03-B. Surface roughing of a cut slope by stair-stepping, with the vertical cut distance less than the horizontal cut distance.

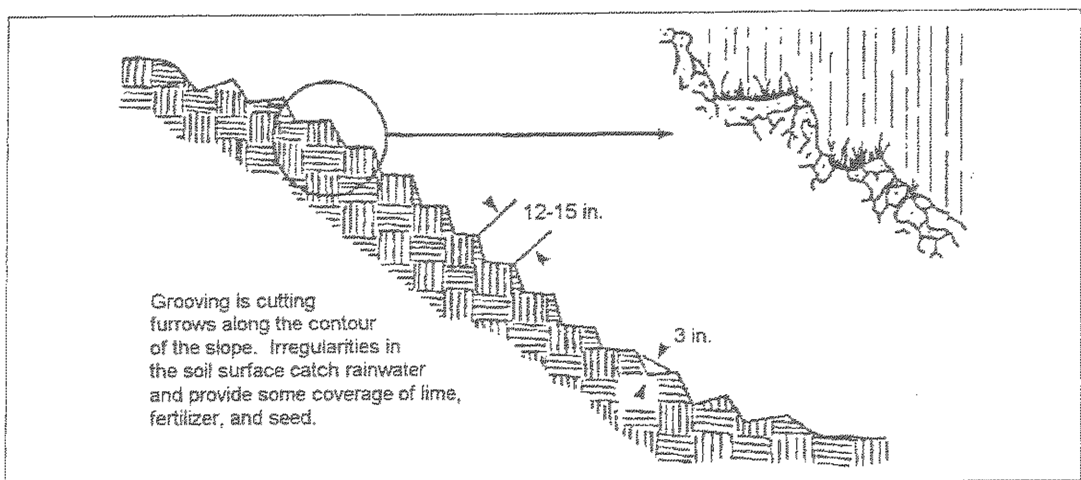


Exhibit 3.03-C. Surface roughening of a cut slope by grooving on the contour.

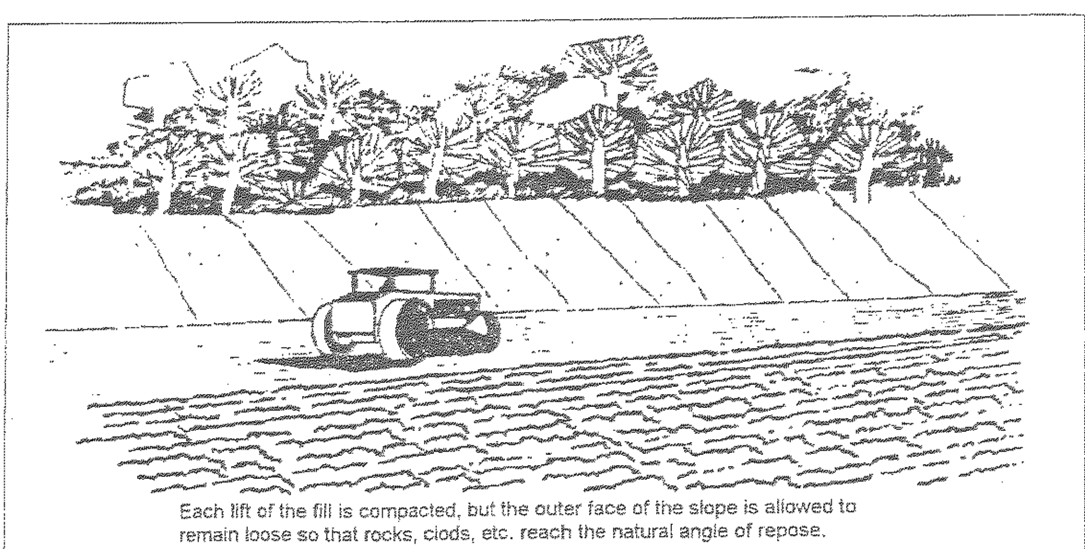


Exhibit 3.03-D. Fill-slope treatment for an area that is not to be mowed.

2. Using a tiller, disk, harrow, or cultipacker to roughen the slopes, creating shallow grooves no more than 10 in. apart and at least 1 in. deep.
3. Make the final pass of tillage implement on the contour.

ROUGHENING AREAS WITH TRACKED MACHINERY:
1. Limit roughening with tracked machinery to sandy or relatively dry, finer-textured soils to avoid undue surface compaction. (Tracking is generally not as effective as the other roughening methods.)
2. Operate the tracked machinery up and down the slope so as to leave horizontal depressions in the soil (see *Exhibit 3.03-E*). (Do not back-blade during the final grading operation.)

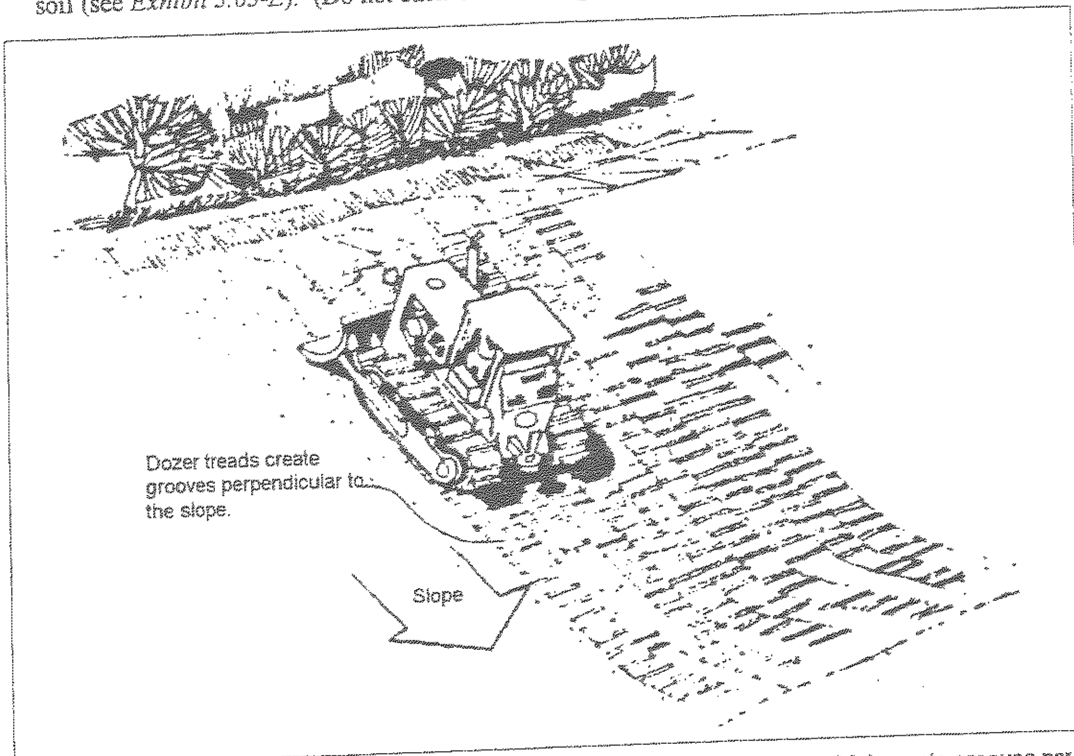


Exhibit 3.03-E. Surface roughening can be done by tracking with bulldozer cleats, which create grooves perpendicular to the slope.

SEEDING/FERTILIZING/MULCHING ROUGHENED AREAS:
1. Immediately seed, fertilize, and mulch surface-roughened areas while soil is loose and moist to aid germination and growth (Practices 3.11, 3.12, and 3.15).
2. If roughening with tracked machinery, consider seeding, fertilizing, and mulching first, letting the cleats incorporate the seed and fertilizer and anchor the mulch. (This is especially well suited for temporary seedings when timeliness is critical and other equipment is unavailable to plant.)

Maintenance

* Periodically check seeded slopes for rills and gullies.
* Fill any eroded areas to slightly above the original grade, then re-seed and mulch as soon as possible.

Common concerns

Severe compaction due to equipment operation—results in unsuitable seedbed and poor vegetative establishment.

Rough areas difficult to mow—caused by cutting grooves too deep or excessive erosion from grooves not being on the contour.

Grooving done perpendicular, rather than parallel, to slope—results in accelerated erosion.

Sub-Section 3.1

SURFACE STABILIZATION

3.11 Temporary Seeding

3.12 Permanent Seeding

3.13 Dormant and Frost Seeding

3.14 Sodding

3.15 Mulching

3.16 Riprap

3.17 Erosion Control Blanket (Surface Applied)

3.18 Turf Reinforcement Mat (Buried)

Practice 3.11
Temporary Seeding

Purpose
(Exhibit 3.11-A)

* To reduce erosion and sedimentation damage by stabilizing disturbed areas where additional work (e.g., grading) is not scheduled for a period of 2 mo. to 1 yr.
* To reduce problems associated with mud or dust from bare soil surfaces during construction.
* To reduce sediment runoff to downstream areas.
* To improve visual aesthetics of the construction areas.

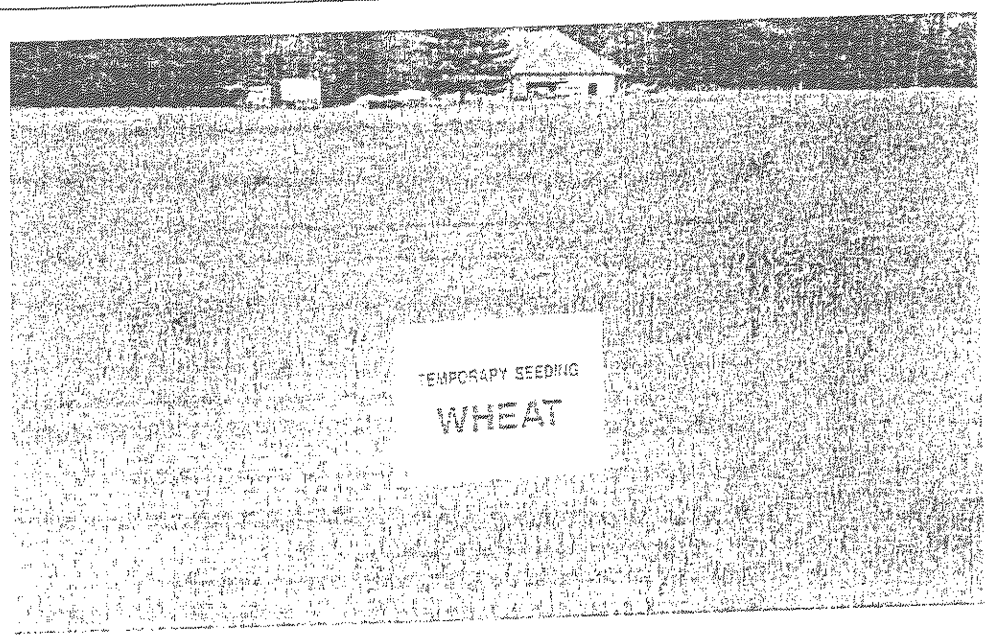


Exhibit 3.11-A. A temporary seeding of wheat to reduce erosion on a future home lot.

Requirements

Site and seedbed preparation: Graded and fertilizer applied.
Plant species: Selected on the basis of quick germination, growth, and time of year to be seeded (see *Exhibit 3.11-B*).
Mulch: Clean grain straw, hay, wood fibre, etc., to protect seedbed and encourage plant growth.
Seeding frequency: As often as possible following construction activity. Daily seeding of rough graded areas when the soil is loose and moist is usually most effective.

Application
(Exhibit 3.11-B)

SITE PREPARATION:
1. Install practices needed to control erosion, sedimentation, and water runoff, such as temporary and permanent diversions, sediment traps or basins, silt fences, and straw bale dams (Practices 3.21, 3.22, 3.72, 3.73, 3.74, and 3.75).
2. Grade the site as specified in the construction plan.

SEEDBED PREPARATION:
1. Test soil to determine its nutrient levels. (Contact your county SWCD or Cooperative Extension office for assistance and soils information, including available soil testing services.)
2. Fertilize as recommended by the soil test. If testing is not done, consider applying 400-600 lbs./acre of 12-12-12 analysis, or equivalent, fertilizer.
3. Work the fertilizer into the soil 2-4 in. deep with a disk or rake operated across the slope.

SEEDING:
1. Select a seeding mixture and rate from *Exhibit 3.11-B*, and plant at depth and on dates shown.
2. Apply seed uniformly with a drill or cultipacker-seeder or by broadcasting, and cover to the depth shown in *Exhibit 3.11-B*.

3. If drilling or broadcasting, firm the seedbed with a roller or cultipacker.
4. Mulch seeded areas to increase seeding success. Anchor all mulch by crimping or tackifying. Use of netting or erosion control blankets is possible, but may not be cost-effective for temporary seedings.

Exhibit 3.11-B. Temporary Seeding Recommendations.

Seed species*	Rate/acre	Planting depth	Optimum dates**
Wheat or rye	150 lbs.	1 to 1½ in.	9/15 to 10/30
Spring oats	100 lbs.	1 in.	3/1 to 4/15
Annual ryegrass	40 lbs.	1/4 in.	3/1 to 5/1
			8/1 to 9/1
German millet	40 lbs.	1 to 2 in.	5/1 to 6/1
Sudangrass	35 lbs.	1 to 2 in.	5/1 to 7/30

* Perennial species may be used as a temporary cover, especially if the area to be seeded will remain idle for more than a year (Practice 3.12).

** Seeding done outside the optimum dates increases the chances of seeding failure.

Maintenance

* Inspect periodically after planting to see that vegetative stands are adequately established; re-seed if necessary.
* Check for erosion damage after storm events and repair; reseed and mulch if necessary.
* Topdress fall seeded wheat or rye seedings with 50 lbs./acre of nitrogen in February or March if nitrogen deficiency is apparent. (*Exhibit 3.11-B* shows only wheat/rye fall seeded.)

Common concern

Fertilizer not incorporated at least 2 in. deep—may be lost in runoff or remain concentrated near the surface to inhibit germination.

Mulch rate inadequate—results in poor germination and failure.

Seeding uneven or rate too low—results in patchy growth and erosion.

Practice 3.12
Permanent Seeding

Purposes
(Exhibit 3.12-A)

* To reduce erosion and sedimentation damage by stabilizing exposed areas where additional work (e.g., grading) is not scheduled for a period of more than a year or areas where final grading has been completed.
* To reduce problems associated with mud or dust from bare soil surfaces during construction.
* To reduce sediment runoff to downstream areas.
* To improve the visual aesthetics of the construction area.

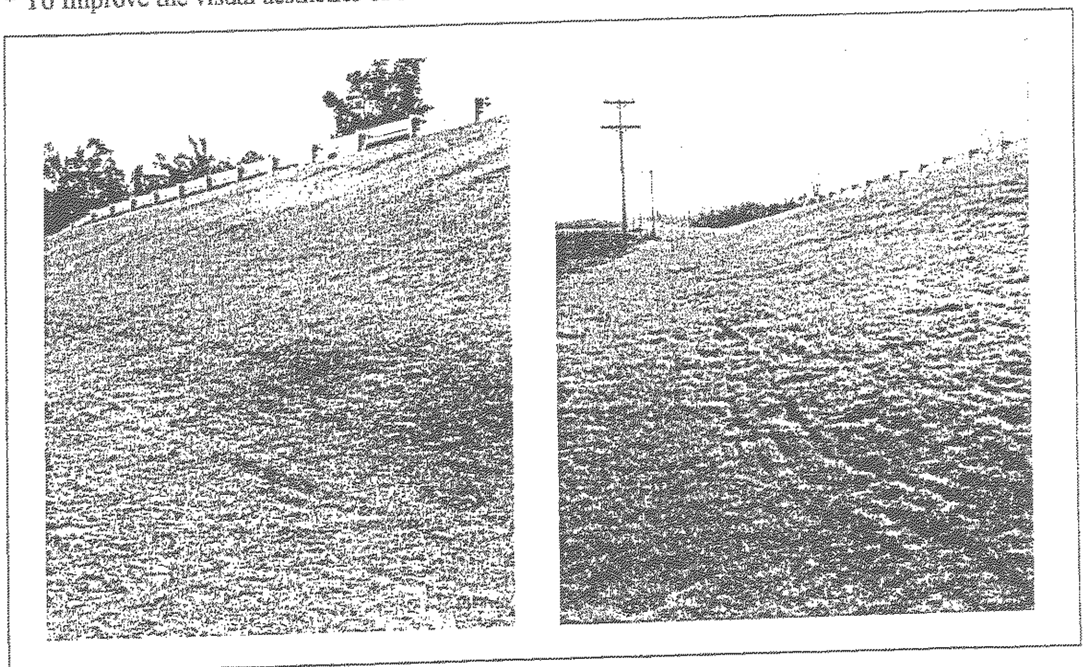


Exhibit 3.12-A. A road right-of-way (left) newly permanent seeded and mulched and (right) 6 mo. later.

Requirements

Site and seedbed preparation: Graded, and lime and fertilizer applied.

Plant species: Selected on the basis of soil type, soil pH, region of the state, time of year, and planned use of the area to be seeded (see *Exhibit 3.12-C*).

Mulch: Clean grain straw, hay, wood fibre, etc., to protect seedbed and encourage plant growth. The mulch may need to be anchored to reduce removal by wind or water, or erosion control blankets may be considered.

Application
(Exhibits 3.12-B, C, and D)

Permanently seed all final grade areas (e.g., landscape berms, drainage swales, erosion control structures, etc.) as each is completed and all areas where additional work is not scheduled for a period of more than a year.

SITE PREPARATION:

1. Install practices needed to control erosion, sedimentation, and runoff prior to seeding. These include temporary and permanent diversions, sediment traps and basins, silt fences, and straw bale dams (Practices 3.21, 3.22, 3.72, 3.73, 3.74, and 3.75).
2. Grade the site and fill in depressions that can collect water.
3. Add topsoil to achieve needed depth for establishment of vegetation (Practice 3.02).

SEEDBED PREPARATION:

1. Test soil to determine pH and nutrient levels. (Contact your county SWCD or Cooperative Extension office for assistance and soils information, including available testing services.)
2. If soil pH is unsuitable for the species to be seeded, apply lime according to test recommendations.

3. Fertilize as recommended by the soil test. If testing was not done, consider applying 400-600 lbs./acre of 12-12-12 analysis, or equivalent, fertilizer.
4. Till the soil to obtain a uniform seedbed, working the fertilizer and lime into the soil 2-4 in. deep with a disk or rake operated across the slope *(Exhibit 3.12-B)*.

SEEDING:

Optimum seeding dates are Mar. 1-May 10 and Aug. 10-Sept. 30. Permanent seeding done between May 10 and Aug. 10 may need to be irrigated. As an alternative, use temporary seeding (Practice 3.11) until the preferred date for permanent seeding.

1. Select a seeding mixture and rate from *Exhibit 3.12-C*, based on site conditions, soil pH, intended land use, and expected level of maintenance.
2. Apply seed uniformly with a drill or cultipacker-seeder *(Exhibit 3.12-D)* or by broadcasting, and cover to a depth of 1/4-1/2 in.
3. If drilling or broadcasting, firm the seedbed with a roller or cultipacker.
4. Mulch all seeded areas (Practice 3.15). Consider using erosion control blankets on sloping areas (Practice 3.17). (NOTE: If seeding is done with a hydroseeder, fertilizer and mulch can be applied with the seed in a slurry mixture.)

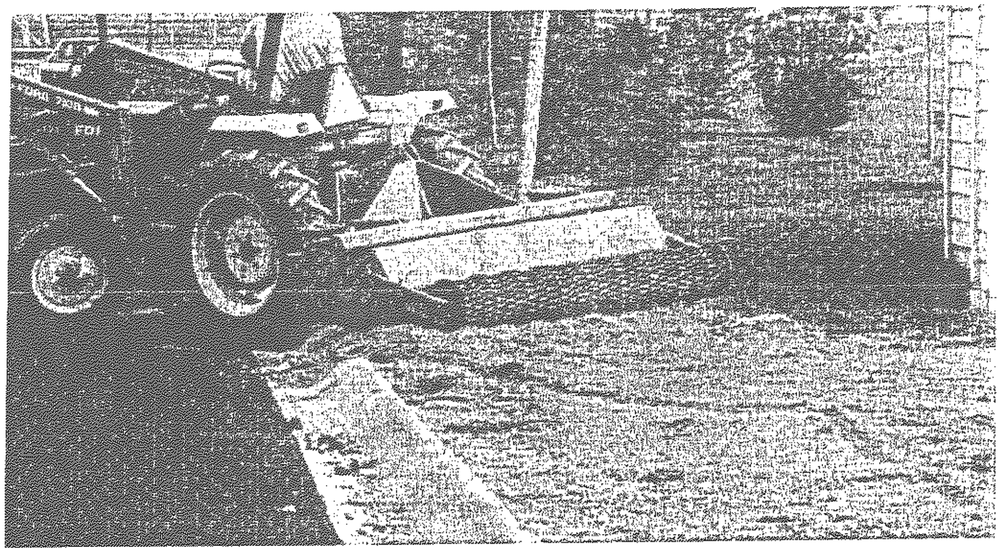


Exhibit 3.12-B. Preparing the seedbed with a combination roto-tiller and cultipacker.

Exhibit 3.12-C. Permanent Seeding Recommendations.

This table provides several seeding options. Additional seed species and mixtures are available commercially. When selecting a mixture, consider site conditions, including soil properties (e.g., soil pH and drainage), slope aspect and the tolerance of each species to shade and droughtiness.

Seed species and mixtures	Rate per acre	Optimum soil pH
OPEN AND DISTURBED AREAS (REMAINING IDLE MORE THAN 1 YR.)		
1. Perennial ryegrass	35 to 50 lbs.	5.6 to 7.0
+ white or ladino clover*	1 to 2 lbs.	
2. Kentucky bluegrass	20 lbs.	5.5 to 7.5
+ smooth bromegrass	10 lbs.	
+ switchgrass	3 lbs.	
+ timothy	4 lbs.	
+ perennial ryegrass	10 lbs.	
+ white or ladino clover*	1 to 2 lbs.	

Exhibit 3.12-C. Continued.

Seed species and mixtures	Rate per acre	Optimum soil pH
3. Perennial ryegrass	15 to 30 lbs.	5.6 to 7.0
+ tall fescue**	15 to 30 lbs.	
4. Tall fescue**	35 to 50 lbs.	5.5 to 7.5
+ ladino or white clover*	1 to 2 lbs.	
STEEP BANKS AND CUTS, LOW MAINTENANCE AREAS (NOT MOWED)		
1. Smooth bromegrass	25 to 35 lbs.	5.5 to 7.5
+ red clover*	10 to 20 lbs.	
2. Tall fescue**	35 to 50 lbs.	5.5 to 7.5
+ white or ladino clover*	1 to 2 lbs.	
3. Tall fescue**	35 to 50 lbs.	5.5 to 7.5
+ red clover*	10 to 20 lbs.	
(Recommended north of US 40)		
4. Orchardgrass	20 to 30 lbs.	5.6 to 7.0
+ red clover*	10 to 20 lbs.	
+ ladino clover*	1 to 2 lbs.	
5. Crownvetch*	10 to 12 lbs.	5.6 to 7.0
+ tall fescue**	20 to 30 lbs.	
(Recommended south of US 40)		
LAWNS AND HIGH MAINTENANCE AREAS		
1. Bluegrass	105 to 140 lbs.	5.5 to 7.0
2. Perennial ryegrass (turf-type)	45 to 60 lbs.	5.6 to 7.0
+ bluegrass	70 to 90 lbs.	
3. Tall fescue (turf-type)**	130 to 170 lbs.	5.6 to 7.5
+ bluegrass	20 to 30 lbs.	
CHANNELS AND AREAS OF CONCENTRATED FLOW		
1. Perennial ryegrass	100 to 150 lbs.	5.6 to 7.0
+ white or ladino clover*	1 to 2 lbs.	
2. Kentucky bluegrass	20 lbs.	5.5 to 7.5
+ smooth bromegrass	10 lbs.	
+ switchgrass	3 lbs.	
+ timothy	4 lbs.	
+ perennial ryegrass	10 lbs.	
+ white or ladino clover*	1 to 2 lbs.	
3. Tall fescue**	100 to 150 lbs.	5.5 to 7.5
+ ladino or white clover*	1 to 2 lbs.	
4. Tall fescue**	100 to 150 lbs.	5.5 to 7.5
+ Perennial ryegrass	15 to 20 lbs.	
+ Kentucky bluegrass	15 to 20 lbs.	

* For best results: (a) legume seed should be inoculated; (b) seeding mixtures containing legumes should preferably be spring-seeded, although the grass may be fall-seeded and the legume frost-seeded (Practice 3.13); and (c) if legumes are fall-seeded, do so in early fall.

** Tall fescue provides little cover for, and may be toxic to, some species of wildlife. The IDNR rec-ognizes the need for additional research on alternatives to tall fescue, such as buffalograss, orchard-grass, smooth brome-grass, and switch-grass. This research, in conjunction with demonstration areas, should focus on erosion control characteristics, wildlife toxicity, turf durability, and drought resistance.

NOTE: An oat or wheat companion or nurse crop may be used with any of the above permanent seeding mixtures. If so, it is best to seed during the fall seeding period, especially after Sept. 15, and at the following rates: spring oats--1/4 to 3/4 bu./acre; wheat--no more than 1/2 bu./acre.

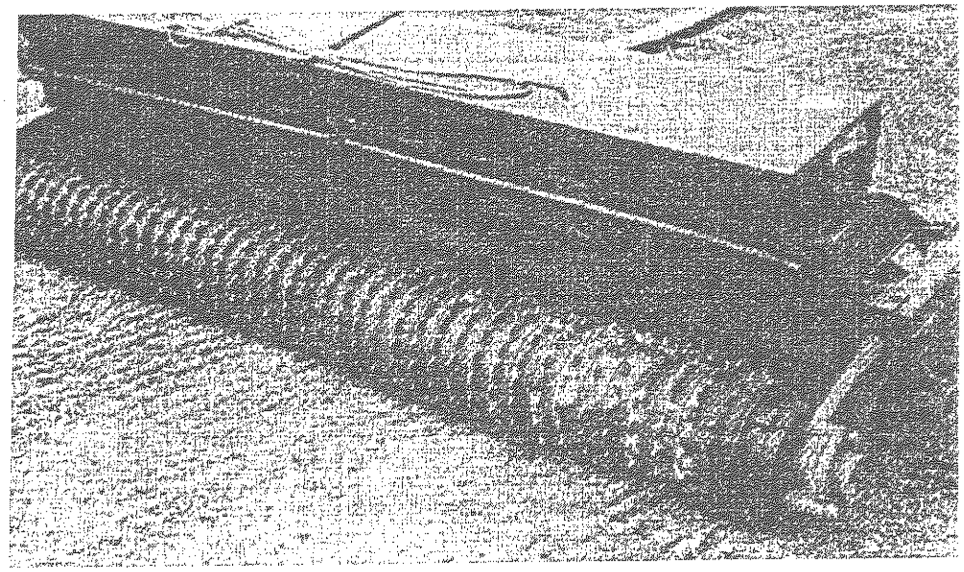


Exhibit 3.12-D. A cultipacker-seeder.

Maintenance

* Inspect periodically, especially after storm events, until the stand is successfully established. (Characteristics of a successful stand include: vigorous dark green or bluish-green seedlings; uniform density with nurse plants, legumes, and grasses well inter-mixed; green leaves; and the perennials remaining green throughout the summer, at least at the plant base.)
* Plan to add fertilizer the following growing season according to soil test recommendations.
* Repair damaged, bare, or sparse areas by filling any gullies, re-fertilizing, over- or re-seeding, and mulching.
* If plant cover is sparse or patchy, review the plant materials chosen, soil fertility, moisture condition, and mulching; then repair the affected area either by over-seeding or by re-seeding and mulching after re-preparing the seedbed.
* If vegetation fails to grow, consider soil testing to determine acidity or nutrient deficiency problems. (Contact your SWCD or Cooperative Extension office for assistance.)
* If additional fertilization is needed to get a satisfactory stand, do so according to soil test recommendations.

Common concerns

Insufficient topsoil or inadequately tilled, limed, and/or fertilized seedbed—results in poor establishment of vegetation.

Unsuitable species or seeding mixture—results in poor establishment of vegetation.

Nurse crop rate too high in the mixture—results in competition with the perennials.

Seeding done at the wrong time of year—results in poor establishment of vegetation, also plant hardiness is significantly decreased.

Mulch rate inadequate—results in poor germination and failure.

Practice 3.13
Dormant and Frost Seeding

Dormant seeding is a temporary or permanent seeding application at a time when soil temperatures are too low for germination to occur (less than 50°F). *Frost seeding* is a temporary or permanent seeding application in early spring when soils are in the freeze-thaw stage. (This practice can be used to repair or enhance areas having thin or declining cover or to re-vegetate an area.)

Purposes
(Exhibit 3.13-A)

* To provide early germination and soil stabilization in the spring.
* To reduce sediment runoff to downstream areas.
* To improve the visual aesthetics of the construction area.
* To repair previous seedings.

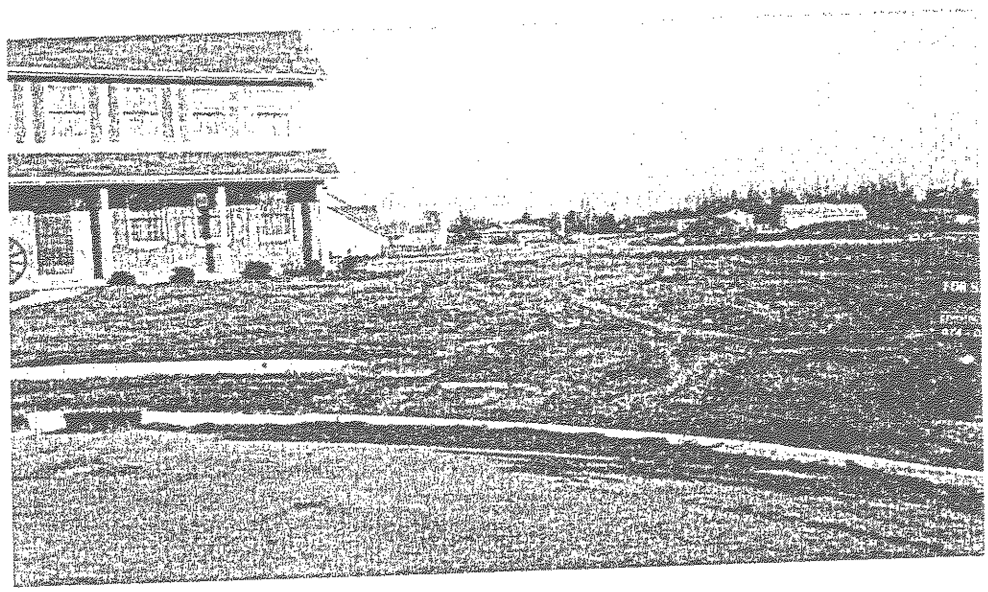


Exhibit 3.13-A. Use of dormant seeding could have reduced excessive early spring erosion on this site.

Requirements

Site and seedbed preparation: Graded as needed, and lime and fertilizer applied.
Plant species: Selected on the basis of soil type, adaptability to the region, and planned use of the area (see *Exhibits 3.13-B* and *3.13-C*).

Application
(Exhibits 3.13-B and C)

SITE PREPARATION:

1. Grade the area to be seeded.
2. Install needed erosion/water runoff control practices, such as temporary or permanent diversions, sediment basins, silt fences, or straw bale dams (Practices 3.21, 3.22, 3.72, 3.74, or 3.75).

FOR DORMANT SEEDING:

Site and seedbed preparation and mulching can be done months ahead of actual seeding; or if the existing ground cover is adequate, seeding can be done directly into it.

Seeding dates: Dec. 1-Feb. 28 (north of U.S. 40), Dec. 10-Jan. 15 (south of U.S. 40).

1. Broadcast fertilizer as recommended by a soil test; or if testing was not done, consider applying 400-600 lbs./acre of 12-12-12 analysis, or equivalent, fertilizer.
2. Apply mulch upon completion of grading (Practice 3.15).
3. Select an appropriate seed species or mixture from *Exhibit 3.13-B* for temporary seeding or *Exhibit 3.13-C* for permanent seeding, and broadcast on top of the mulch and/or into existing ground cover at the rate shown. (If site preparation occurs within the recommended dates, fertilize and lime, seed, and mulch at that time.)

FOR FROST SEEDING:

Seed is broadcast over the prepared seedbed and incorporated into the soil by natural freeze-thaw action.

Seeding dates: Feb. 28-Mar. 28 (north of U.S. 40), Feb. 15-Mar. 15 (south of U.S. 40).

1. Broadcast fertilizer as recommended by a soil test; or if testing was not done, consider applying 400-600 lbs./acre of 12-12-12 analysis, or equivalent, fertilizer.
2. Select an appropriate seed species or mixture from *Exhibit 3.13-B* for temporary seeding or *Exhibit 3.13-C* for permanent seeding, and broadcast on to the seedbed or into the existing ground cover at the rate shown. (Do not work the seed into the soil.)

Exhibit 3.13-B. Temporary Dormant or Frost Seeding Recommendations.

Seed species*	Rate per acre
Wheat or rye	150 lbs.
Spring oats	150 lbs.
Annual ryegrass	60 lbs.

* Perennial species may be used as a temporary cover, especially if the area to be seeded will remain idle for more than a year (Practice 3.12).

Exhibit 3.13-C. Permanent Dormant or Frost Seeding Recommendations.

This table provides several seeding options. Additional seed species and mixtures are available commercially. When selecting a mixture, consider site conditions, including soil properties (e.g., soil pH and drainage), slope aspect and the tolerance of each species to shade and droughtiness.

Seed species and mixtures	Rate per acre	Optimum soil pH
OPEN AND DISTURBED AREAS (REMAINING IDLE MORE THAN 1 YR.)		
1. Perennial ryegrass	50 to 75 lbs.	5.6 to 7.0
+ white or ladino clover*	1½ to 3 lbs.	
2. Kentucky bluegrass	30 lbs.	5.5 to 7.5
+ smooth bromegrass	15 lbs.	
+ switchgrass	5 lbs.	
+ timothy	6 lbs.	
+ perennial ryegrass	15 lbs.	
+ white or ladino clover*	1½ to 3 lbs.	
3. Perennial ryegrass	22 to 45 lbs.	5.6 to 7.0
+ tall fescue**	22 to 45 lbs.	
4. Tall fescue**	50 to 75 lbs.	5.5 to 7.5
+ ladino or white clover*	1½ to 3 lbs.	
STEEP BANKS AND CUTS, LOW MAINTENANCE AREAS (NOT MOWED)		
1. Smooth bromegrass	35 to 50 lbs.	5.5 to 7.5
+ red clover*	15 to 30 lbs.	
2. Tall fescue**	50 to 75 lbs.	5.5 to 7.5
+ white or ladine clover*	1½ to 3 lbs.	
3. Tall fescue**	50 to 75 lbs.	5.5 to 7.5
+ red clover*	15 to 30 lbs.	
(Recommended north of US 40)		
4. Orchardgrass	30 to 45 lbs.	5.6 to 7.0
+ red clover*	15 to 30 lbs.	
+ ladino clover*	1½ to 3 lbs.	
5. Crownvetch*	15 to 18 lbs.	5.6 to 7.0
+ tall fescue**	30 to 45 lbs.	
(Recommended south of US 40)		

Exhibit 3.13-C. Continued.

Seed species and mixtures	Rate per acre	Optimum soil pH
LAWNS AND HIGH MAINTENANCE AREAS		
1. Bluegrass	160 to 210 lbs.	5.5 to 7.0
2. Perennial ryegrass (turf-type)	70 to 90 lbs.	5.6 to 7.0
+ bluegrass	105 to 135 lbs.	
3. Tall fescue (turf-type)**	195 to 250 lbs.	5.6 to 7.5
+ bluegrass	30 to 45 lbs.	
CHANNELS AND AREAS OF CONCENTRATED FLOW		
1. Perennial ryegrass	150 to 225 lbs.	5.6 to 7.0
+ white or ladino clover*	1½ to 3 lbs.	
2. Kentucky bluegrass	30 lbs.	5.5 to 7.5
+ smooth bromegrass	15 lbs.	
+ switchgrass	5 lbs.	
+ timothy	6 lbs.	
+ perennial ryegrass	15 lbs.	
+ white or ladino clover*	1½ to 3 lbs.	
3. Tall fescue**	150 to 225 lbs.	5.5 to 7.5
+ ladino or white clover*	1½ to 3 lbs.	
4. Tall fescue**	150 to 225 lbs.	5.5 to 7.5
+ Perennial bluegrass	22 to 30 lbs.	
+ Kentucky bluegrass	22 to 30 lbs.	

* For best results: (a) legume seed should be inoculated; (b) seeding mixtures containing legumes should preferably be spring-seeded, although the grass may be fall-seeded and the legume frost-seeded; and (c) if legumes are fall-seeded, do so in early fall.

** Tall fescue provides little cover for, and may be toxic to, some species of wildlife. The IDNR recognizes the need for additional research on alternatives to tall fescue, such as buffalograss, orchardgrass, smooth bromegrass, and switch-grass. This research, in conjunction with demonstration areas, should focus on erosion control characteristics, wildlife toxicity, turf durability, and drought resistance.

NOTE: If using mixtures other than those listed here, increase the seeding rate by 50% over the conventional rate.

Maintenance

- Apply 200-300 lbs./acre of 12-12-12 or equivalent fertilizer between Apr. 15 and May 10 or during periods of vigorous growth.
- Re-seed and mulch any areas that have inadequate cover by mid- to late-April. For best results, re-seed within the recommended dates shown in Practices 3.11 for temporary seeding or 3.12 for permanent seeding.

Common concerns

Seeding done at wrong time of year--results in poor seed germination and vegetative stands.

Seeding on too steep a slope--results in seed loss and poor stands.

Seeding failure due to late freeze, killing germinated seedlings.

Mulch rate inadequate--results in poor germination and failure of dormant seeding.

Unsuitable choice of seed species or seeding mixture--results in poor vegetative stands or vegetation that does not serve the intended purpose.

Poor soil and seed contact--results in poor seed germination and vegetative stands.

Dormant seeding over mulch or frost seeding in concentrated flow areas--can result in seed being washed away before seed-soil contact and germination can occur.

Practice 3.14
Sodding

Purposes
(Exhibit 3.14-A)

* To stabilize disturbed areas by establishing permanent grass stands with sod.
* To provide immediate vegetative cover of critical areas, channels, and sediment control structures.
* To prevent erosion and damage from sedimentation and runoff.
* To reduce the problems associated with mud or dust from bare soil surfaces.

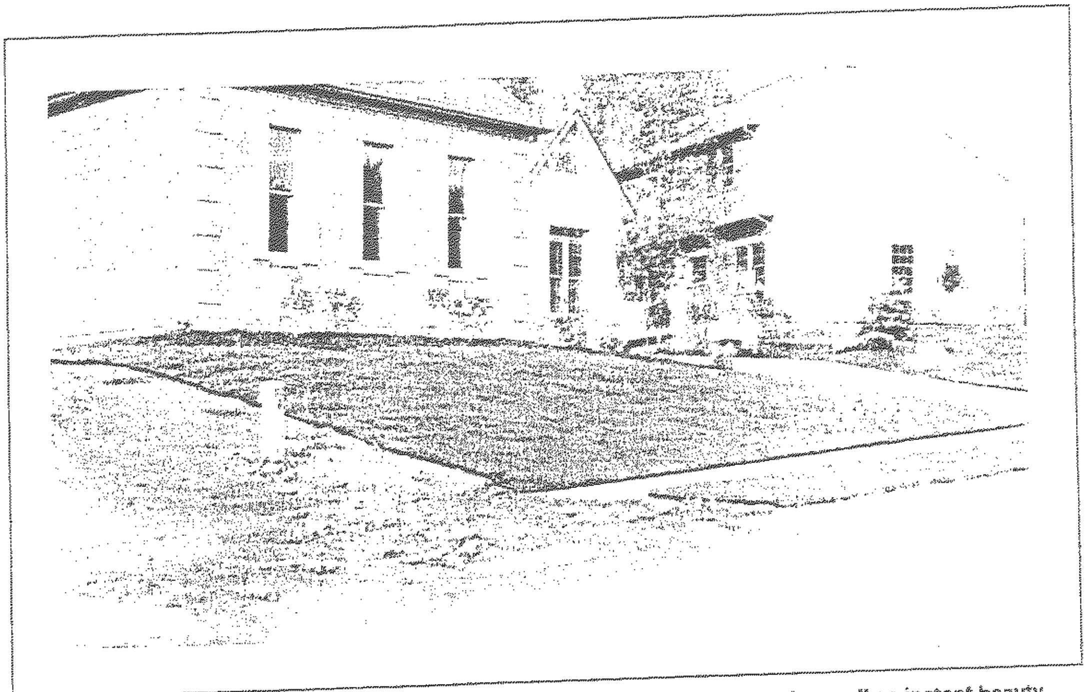


Exhibit 3.14-A. Grass sod installed on a homesite brings instant erosion control as well as instant beauty.

Requirements

Site and seedbed preparation: A smooth, firm soil surface, with lime and fertilizer applied.

Plant material: High-quality, healthy, vigorous sod of a variety well-adapted to the region and compatible with the intended use. (Selection of varieties is usually much more limited than when establishing vegetation from seed.)

Irrigation: As needed to ensure rooting of sod.

Installation
(Exhibits 3.14-B, C, and D)

Sod should not be installed on hot, dry soil, frozen soil, compacted clay, gravel, or pesticide-treated soil. The ideal time to sod is May 1-June 1 or Sept. 1-Oct. 20, although it can be installed as early as Mar. 15 if available and temperatures are above 32°F or June 1-Sept. 1 if irrigated. (To help retain moisture when irrigating, cover the sod with a uniform layer of straw mulch 1/2 in. thick or so the grass is barely visible through the mulch.)

SITE PREPARATION:

1. Install any practices needed to control erosion, sedimentation, and runoff, such as diversions, sediment basins, silt fences, and straw bale dams (Practices 3.21, 3.22, 3.72, 3.74, and 3.75).
2. Break up compacted soils sufficiently to create a favorable rooting depth of 6-8 in., using a chisel, disk, harrow, or rake.
3. Apply topsoil if the site is otherwise unsuited for establishing vegetation (Practice 3.02).
4. Shape, smooth, and firm the soil surface.

SOD-BED PREPARATION:

1. Have the soil in the sod-bed tested to determine its pH and nutrient levels. (Contact your county SWCD or Cooperative Extension office for assistance and soils information, including available testing services.)

2. If soil pH is too acidic for the grass sod to be installed, apply lime according to test results or at the rate recommended by the sod supplier.
3. Fertilize as recommended by the soil test. If testing was not done, consider applying 400-600 lbs./acre of 12-12-12 analysis, or equivalent, fertilizer.
4. Work the fertilizer and lime into the soil to 2-4 in. deep with a disk or rake operated across the slope.
5. Rake or harrow to achieve a smooth final grade, then roll or culti-pack to create a firm surface on which to lay the sod.

LAYING THE SOD:

1. If possible, install sod within 36 hrs. of its harvest (see *Exhibit 3.14-B*).
2. Store the rolls of sod in a shaded place during installation.
3. Immediately before laying, rake the soil surface to break any crust and irrigate lightly if the weather is hot.
4. Lay the strips of sod in a brick-like pattern (see *Exhibit 3.14-C*).
5. Butt all joints tightly against each other (but do not stretch or overlap them); and match angled ends correctly to prevent voids, using a knife or mason's trowel to trim and fit irregularly shaped areas (see *Exhibit 3.14-D*).
6. Roll the sod lightly after installation to ensure a firm soil contact.
8. Irrigate the sodded area until the soil is wet to a depth of 4 in., then keep moist until the grass takes root.

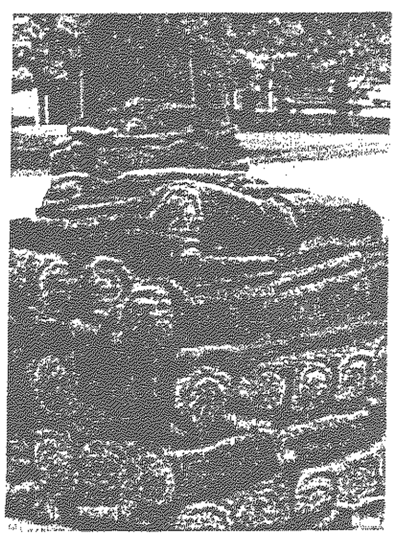


Exhibit 3.14-B. Install rolled sod within 36 hrs. of harvest; keep it shaded at the site.

Exhibit 3.14-C. Lay the strips of sod in a staggered, brick-like fashion.

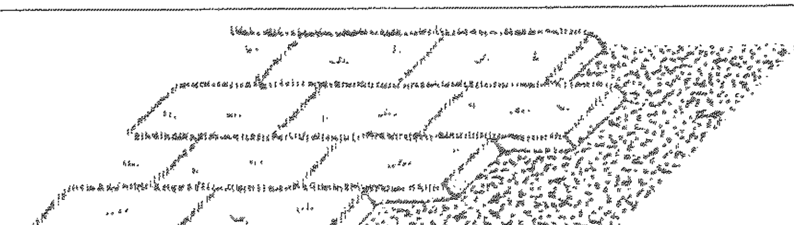


Exhibit 3.14-D. Butt the sod strips tightly against each other, using a sharpened mason's trowel to angle and tuck down the ends.

SLOPE APPLICATION:

1. Install the sod strips with their longest dimension perpendicular to the slope.
2. Where slope exceeds 3:1, staple or stake each strip at the corners and in the middle.

CHANNEL APPLICATION:

(Sodding provides quicker protection than seeding and may reduce the risk of early washout.)

1. Use the type of sod specified in the channel design.
2. Over-cut the channel the full thickness of the sod.
3. Staple or stake each strip at the corners and in the middle.
4. For further protection against washout during establishment, peg jute or biodegradable polypropylene netting over the sodded area .

Maintenance

* Keep sod moist until fully rooted.
* After it is well-rooted (2-3 wks.), mow to a height of 2-3 in.
* Do not remove more than one-third of the shoot in any mowing.
* Fertilize permanent fine turf areas annually—warm-season grass in late spring to early summer, cool-season grass in late winter and again in early fall.

Common concerns

Sod laid on poorly prepared soil or unsuitable surface—grass fails to root and dies.

Sod not adequately irrigated after installation—results in root die-back because the grass does not root rapidly.

Sod not anchored properly—sod may be loosened and displaced by runoff.

Sod laid parallel to channel flow—sod may be dislodged easier in heavy runoff or water may cut rills between sod strips.

Sod not laid in brick-like pattern—allows long continuous channels to develop between the strips.

Practice 3.15
Mulching

Purposes
(Exhibit 3.15-A)

* To prevent erosion by protecting the soil from wind and water impact.
* To provide temporary surface stabilization.
* To prevent soil from crusting.
* To conserve moisture thereby promoting seed germination and seedling growth.

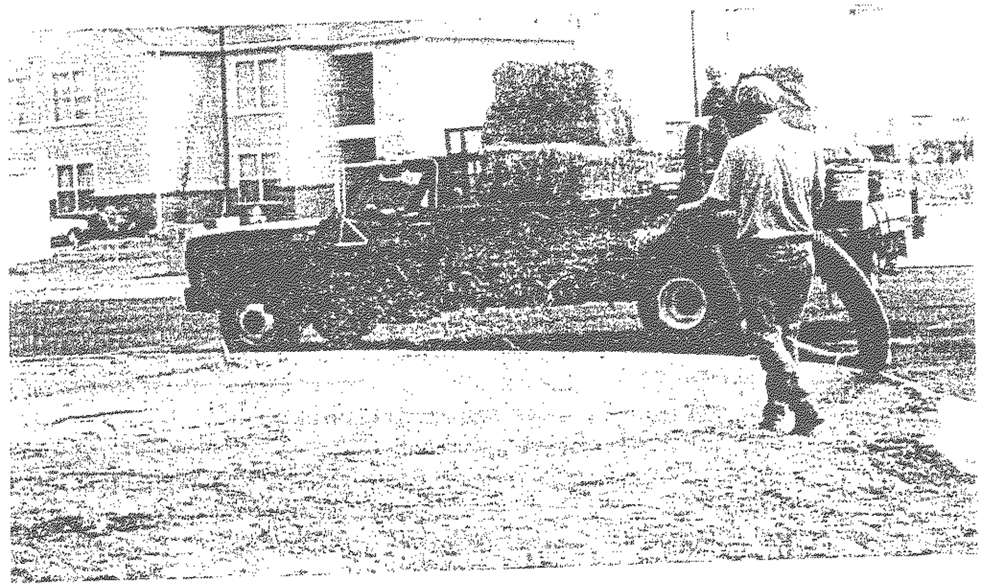


Exhibit 3.15-A. Applying straw mulch with a chopper-blower on freshly seeded soil adjacent to a road.

Requirements
(Exhibits 3.15-B and C)

Material: Straw, hay, wood fiber, cellulose, or excelsior (see *Exhibit 3.15-B*), or erosion control blankets or turf reinforcement mats (Practices 3.17 and 3.18), as specified in the erosion and sediment control plan.

Coverage: At least 75% of the soil surface.

Anchoring: Required for straw or hay mulch and sometimes excelsior to prevent displacement by wind and/or water (see *Exhibit 3.15-C*).

Exhibit 3.15-B. Mulch Materials, Rates, and Comments.

Material	Rate	Comments
Straw or hay	1½-2 tons/acre	Should be dry, unchopped, free of undesirable seeds. Spread by hand or machine. Must be crimped or anchored (see *Exhibit 3.15-D*).
Wood fiber or cellulose	1 ton /acre	Apply with a hydromulcher and use with tacking agent.
Long fiber wood (excelsior)	1/2-3/4 ton/acre	Anchor in areas subject to wind.

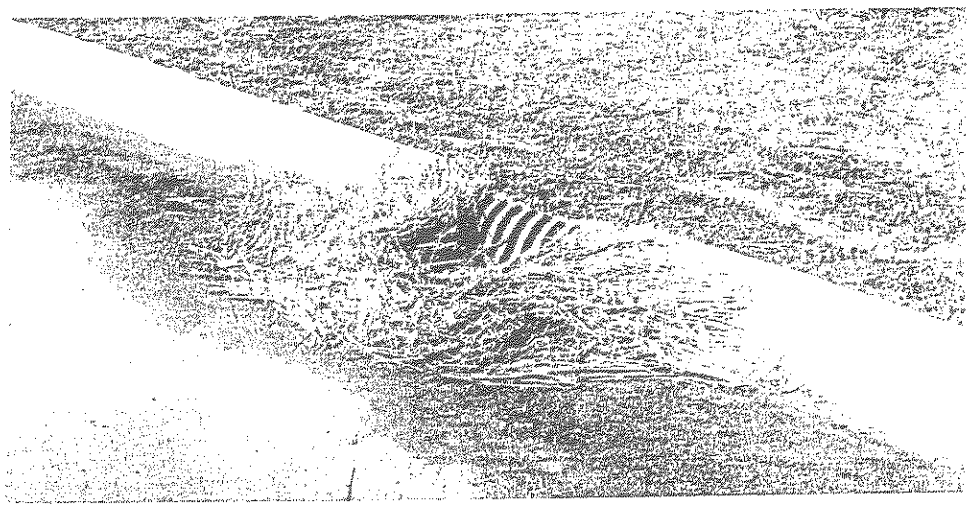


Exhibit 3.15-C. This unanchored straw mulch flowed with runoff to the storm drain. While acting somewhat as an inlet protection filter, it would have been more effective keeping soil from eroding off the site.

Application and anchoring

(Exhibits 3.15-D, E, and F)

1. Apply mulch at the recommended rate.
2. Spread uniformly by hand, hay fork, mulch blower, or hydromulcher. After spreading, no more than 25% of the ground surface should be visible.
3. If straw or hay is used, anchor it immediately one of the following ways (see *Exhibit 3.15-D*):
   - Crimp with a mulch anchoring tool, a weighted farm disk with dull serrated blades set straight (see *Exhibit 3.15-E*), or track cleats of a bulldozer; OR
   - Hydromulch with short cellulose fibers (see *Exhibit 3.15-F*); OR
   - Apply a liquid tackifier; OR
   - Cover with netting secured by metal staples.

Exhibit 3.15-D. Mulch Anchoring Methods.

Anchoring method	How to apply
Mulch anchoring tool OR Farm disk (dull, serrated, and set straight)	Crimp or punch the straw or hay into the soil 2-4 in. Operate machinery on the contour of the slope.
Cleating with dozer tracks	Operate dozer up and down slope, not across, or else the tracks will form rills.
Wood hydromulch fibers	Apply 1-2 tons/acre using a hydromulcher at a rate of 750 lbs./acre with a tacking agent (or according to contractor specifications). Do not use in areas of concentrated flow.
Asphalt emulsion	Emulsified asphalt should conform to the requirements of ASTM Spec. #977. Apply with suitable equipment at a rate of 0.05 gal./sq. yd. Do not use in areas of concentrated flow.
Synthetic tackifier, binder or soil stabilizer	Apply according to manufacturer's recommendation.
Biodegradable netting (polypropylene or similar material)*	Apply over mulch and staple with 6-8 in. wire staples. Follow manufacturer's recommendations for installation. Best suited to slope application.

* Install the netting immediately after applying the mulch. In areas of concentrated water flow, lay it parallel to the direction of flow; on other slopes, lay it either parallel or perpendicular to direction of flow. Edges of adjacent netting strips should overlap 4-6 in., with the strip on the upgrade side of any lateral water flow on top. Installation details are site specific, so follow manufacturer's directions.

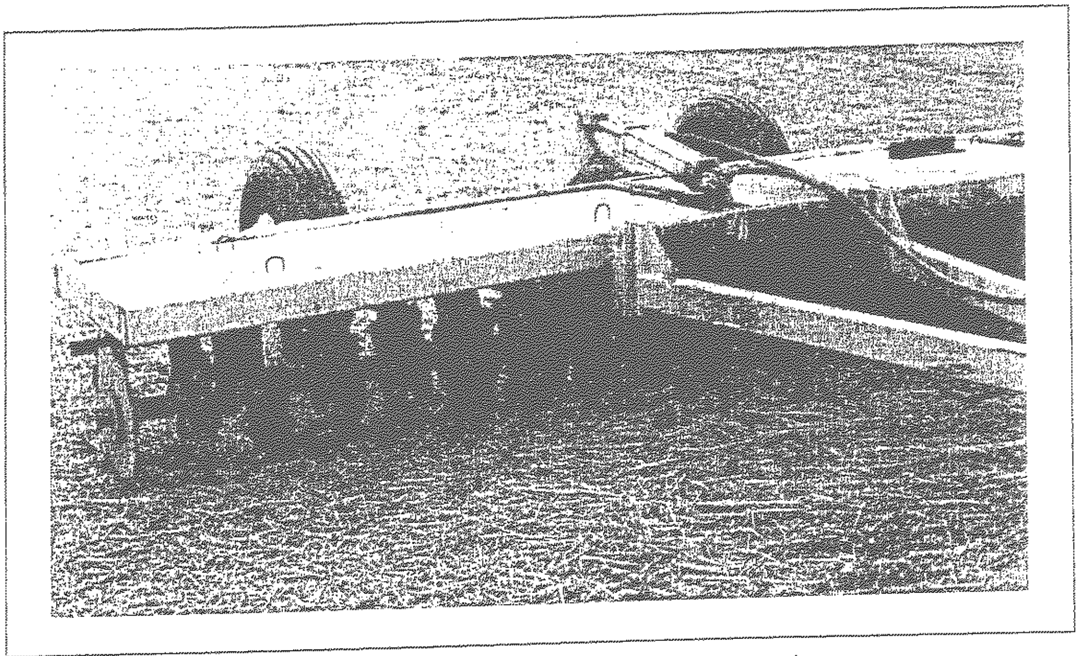


Exhibit 3.15-E. A crimper can be used to anchor mulch into the soil more securely.

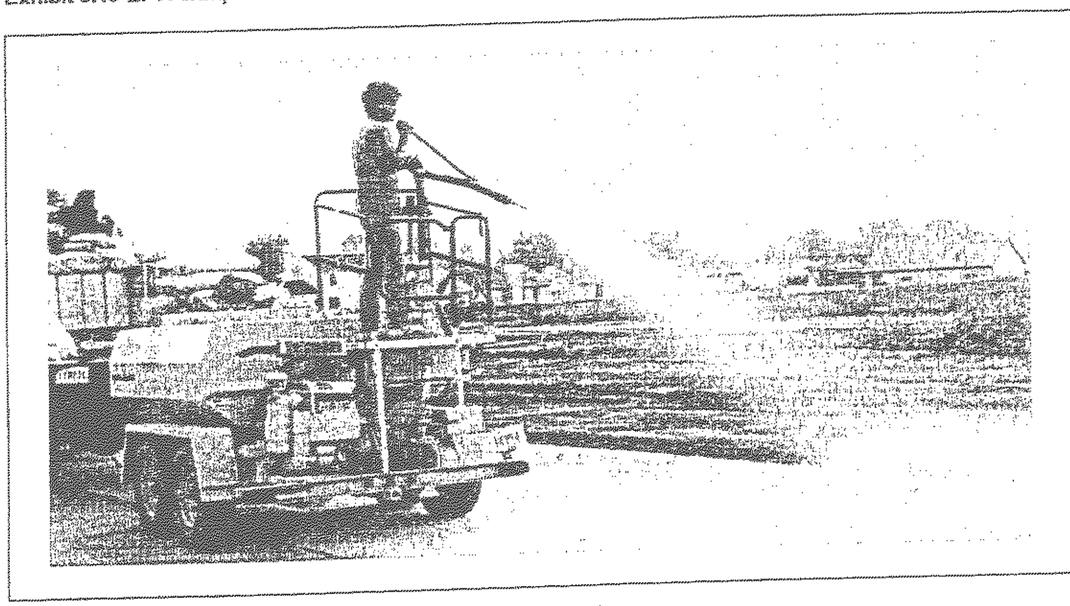


Exhibit 3.15-F. Hydroseeding the roadside in a new subdivision.

Maintenance

* Inspect after storm events to check for movement of mulch or for erosion.
* If washout, breakage, or erosion is present, repair the surface, then re-seed, re-mulch and, if applicable, install new netting.
* Continue inspections until vegetation is firmly established.

Common concerns

Inadequate coverage—results in erosion, washout, and poor plant establishment.

Appropriate tacking agent not applied or applied in insufficient amount—results in mulch being lost to wind and runoff.

Flow too concentrated to use straw mulch—results in erosion in channel; consider use of erosion control blankets and/or a diversion until vegetation is established.

Hydromulch applied in winter—results in deterioration of mulch before plants can become established.

Netting washed away—because insufficient number of staples used.

Practice 3.16
Riprap

Purpose
(Exhibit 3.16-A)

* To protect slopes, streambanks, channels, or similar areas subject to erosion by water.

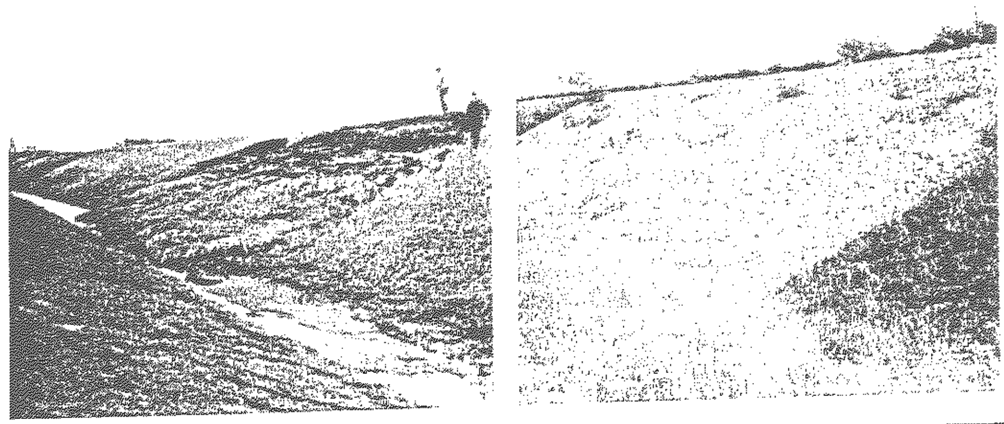


Exhibit 3.16-A. Riprap provides protection on slopes where vegetation is hard to establish because of soil slippage.

Requirements

Rock: Hard, angular, and weather-resistant, having a specific gravity of at least 2.5.
Gradation: Well-graded stone, 50% (by weight) larger than the specified d_{50}; however, the largest pieces should not exceed two times the specified d_{50}, and no more than 15% of the pieces (by weight) should be less than 3 in.
Filter: Use geotextile fabric for stabilization and filtration or sand/gravel layer placed under all permanent riprap installations.
Slope: 2:1 or flatter, unless approved in the erosion and sediment control plan.
Minimum thickness: Two times the specified d_{50} stone diameter.

Installation
(Exhibit 3.16-B)

SUBGRADE PREPARATION:
1. Remove brush, trees, stumps, and other debris.
2. Excavate only deep enough for both filter and riprap; over-excavation increases the amount of spoil considerably (Practice 3.32).
3. Compact any fill material to the density of the surrounding undisturbed soil.

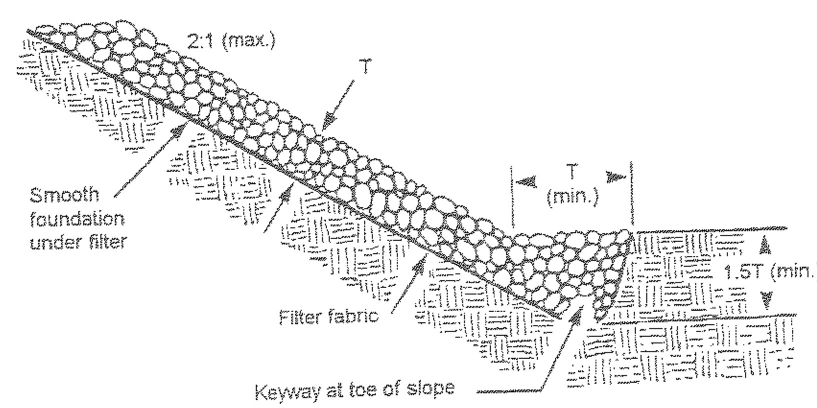


Exhibit 3.16-B. Proper riprap installation on a slope.

4. Cut a keyway in stable material at the base of the slope to reinforce the toe; keyway depth should be 1½ times the design thickness of the riprap and should extend a horizontal distance equal to the design thickness.
5. Smooth the graded foundation.

FILTER PLACEMENT:

1. If using geotextile fabric, place it on the smoothed foundation, overlap the edges at least 12 in., and secure with anchor pins spaced every 3 ft. along the overlap. (For large riprap, consider a 4-in. layer of sand to protect the fabric.)
2. If using a sand/gravel filter, spread the well-graded aggregate in a uniform layer to the required thickness (6 in. minimum); if two or more layers are specified, place the layer of smaller gradation first, and avoid mixing the layers.

RIPRAP PLACEMENT:

1. Immediately after installing the filter, add the riprap to full thickness in one operation. (Do not dump through chutes or use any method that causes segregation of rock sizes or that will dislodge or damage the underlying filter material.)
2. If fabric is damaged, remove the riprap and repair by adding another layer of fabric, overlapping the damaged area by 12 in.
3. Place smaller rock in voids to form a dense, uniform, well-graded mass. (Selective loading at the quarry and some hand placement may be needed to ensure an even distribution of rock material.)
4. Blend the rock surface smoothly with the surrounding area to eliminate protrusions or over-falls.

Maintenance

* Inspect periodically for displaced rock material, slumping, and erosion at edges, especially downstream or downslope. (Properly designed and installed riprap usually requires very little maintenance if promptly repaired.)

Common concerns

Excavation not deep enough—thus riprap blocks the channel, resulting in erosion along edges.
Slope too steep—results in stone displacement. (Do not use riprap as a retaining wall.)
Foundation not properly smoothed for fabric placement—results in damage to the fabric.
Filter omitted or damaged—results in piping or slumping.
Riprap not properly graded—results in stone movement and erosion of the foundation.
Foundation toe not properly reinforced—results in undercutting of riprap slope or slumping.
Fill slopes not properly compacted before placing riprap—results in settlement and stone displacement.

Practice 3.17
Erosion Control Blanket (Surface-Applied)

Erosion control blanket is biodegradable organic or synthetic mulch incorporated into a polypropylene or similar netting material; it is an alternative to mulch and normally used on slopes or in concentrated flow channels.

Purpose
(Exhibit 3.17-A)

* To prevent erosion by protecting the soil from rainfall impact, overland water flow, concentrated runoff, or wind.
* To provide temporary surface stabilization.
* To anchor mulch in critical areas, including slopes.
* To reduce soil crusting.
* To conserve moisture and increase seed germination and seedling growth.

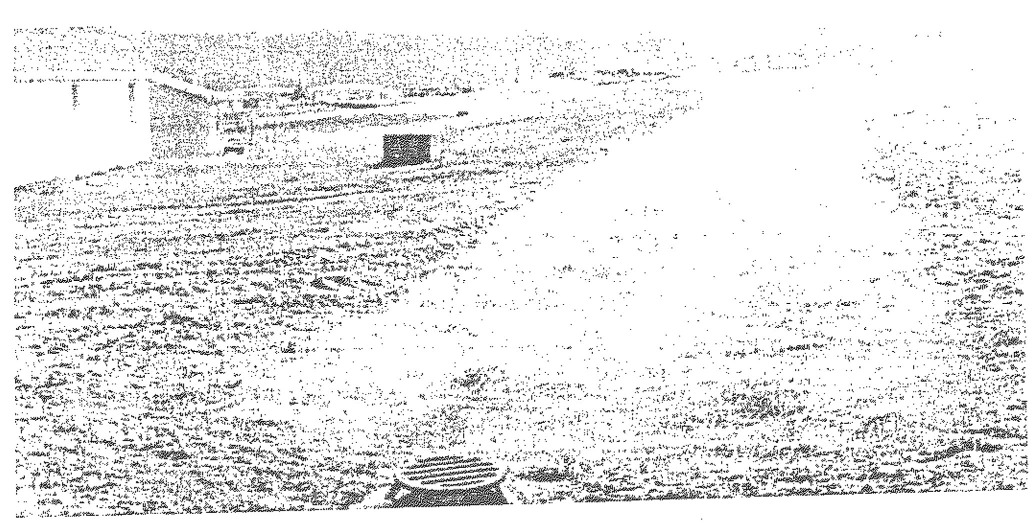


Exhibit 3.17-A. Erosion control blanket installed in a drainage swale.

Requirements

Material: Either an organic (straw, excelsior, woven paper, coconut, fiber, etc.) or a synthetic mulch incorporated into a polypropylene or similar netting material. It may be biodegradable, photodegradable or permanent.

Expected life: 2 yrs. maximum.

Anchoring: Use of staples or stakes to prevent movement or displacement.

Installation
(Exhibit 3.17-B)

1. Select the type and weight of erosion control blanket to fit the site conditions (e.g., slope, channel, flow velocity).
2. Install any practices needed to control erosion and runoff, such as temporary or permanent diversion, sediment basin or trap, silt fence, and straw bale dam (Practices 3.21, 3.22, 3.72, 3.73, 3.74, 3.75).
3. Grade the site as specified in the construction plan.
4. Add topsoil where appropriate (Practice 3.02).
5. Prepare the seedbed, fertilize (and lime, if needed), and seed the area immediately after grading (Practice 3.12).
6. Following manufacturer's directions, lay the blankets on the seeded area such that they are in continuous contact with the soil and that the upslope or upstream ones overlap the lower ones by at least 8 in.
7. Tuck the uppermost edge of the upper blankets into a check slot (slit trench), backfill with soil, and tamp down.

8. Anchor the blankets as specified by the manufacturer. This typically involves driving 6-8 in. metal staples into the ground in a pattern determined by the site conditions.

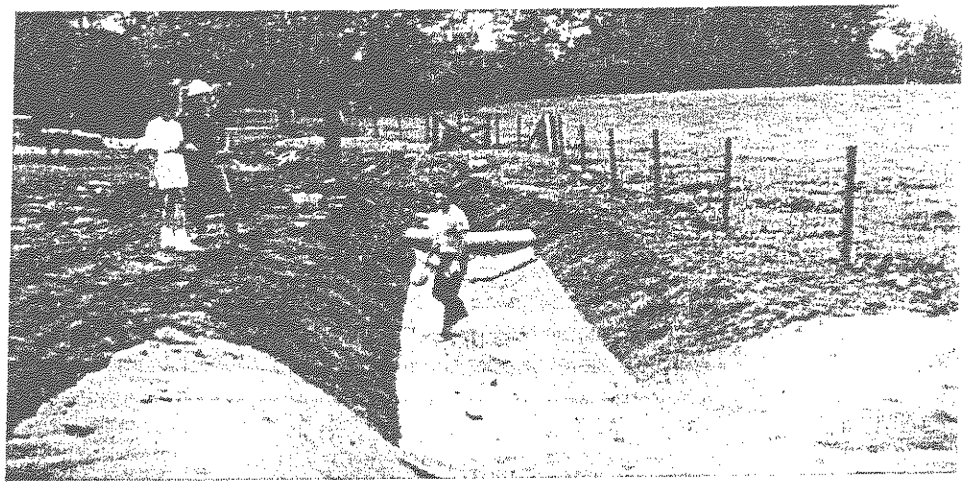


Exhibit 3.17-B. Proper installation of erosion control blankets in a drainageway.

Maintenance

* During vegetative establishment, inspect after storm events for any erosion below the blanket.
* If any area shows erosion, pull back that portion of the blanket covering it, add soil, re-seed the area, and re-lay and staple the blanket.
* After vegetative establishment, check the treated area periodically.

Common concerns

Poor contact between the soil and erosion control blanket—results in surface water flowing under rather than over the blanket, causing erosion.

Blanket inadequately or improperly stapled—results in blanket movement or displacement.

Check slots not used—results in surface water flowing under rather than over the blanket, causing erosion.

Practice 3.18
Turf Reinforcement Mat (Buried)

Purposes
(Exhibit 3.18-A)

* To provide reinforcement to soil and vegetation in areas of concentrated flow or steep slopes where other types of reinforcement, such as riprap or paving, are not feasible or desired.
* To provide surface stabilization.
* To provide reinforcement for plant roots as vegetation is being established.

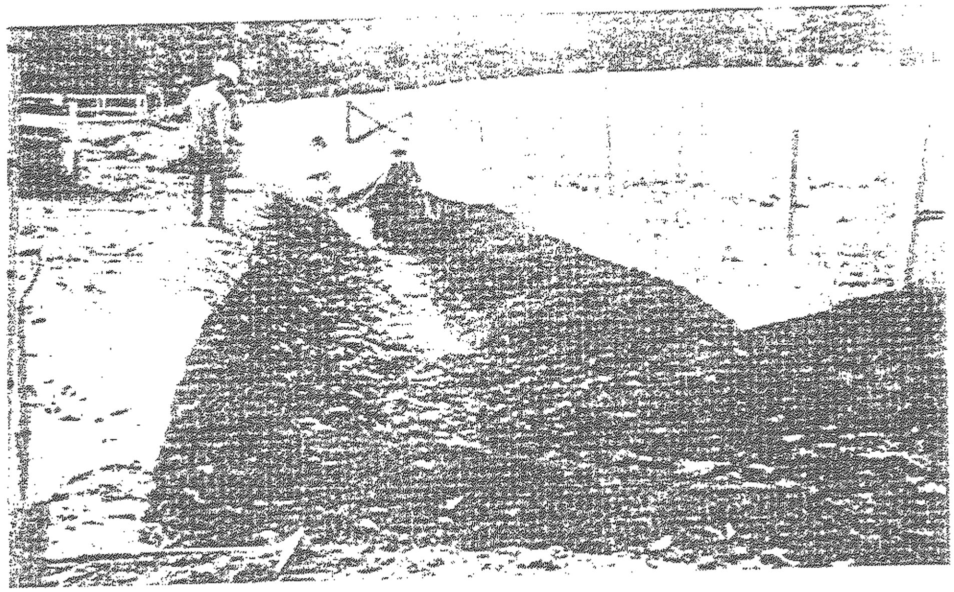


Exhibit 3.18-A. Turf reinforcement mat being installed in a channel.

Requirements

Material: Geotextile fabric for stabilization consisting of three-dimensional matrix of polypropylene, nylon, coconut fibers, or other material (sold under brand names such as Enkamat, Tensar, Geomat, etc.). See manufacturer's recommendations for specific applications.

Expected life: Depends on type used—relatively permanent for synthetic fibers, up to one year for organic fibers.

Anchoring: By stapling, staking, or burying under soil.

Installation

1. Select the type of mat recommended for the site conditions (e.g., slope, channel, flow velocity) and problem to be addressed.
2. Install any practices needed to control erosion and runoff, such as a temporary or permanent diversion, temporary slope drain, sediment basin or trap, silt fence, and straw bale dam (Practices 3.21, 3.22, 3.26, 3.72, 3.73, 3.74, and 3.75).
3. Grade the site as specified in the construction plan where turf reinforcement mat is to be installed.
4. Install the mat according to manufacturer's instructions, including burying the edges in check slots or slot trenches and anchoring with staples or stakes.
5. Backfill topsoil to a depth equal to the thickness of the mat.
6. Seed the area after the mat has been installed and backfilled with soil.
7. Mulch the area, or use erosion control blankets to stabilize the surface.

Maintenance

* Until the surface is stabilized, inspect after storm events for erosion exposing the mat.
* If a specific area shows erosion, add soil and restabilize (Steps 6 and 7 above).

* After the surface is stabilized, the only on-going maintenance is mowing where a short vegetative stand is desired and repairing any washouts.

Common concerns

Manufacturer's recommendations not followed in choosing or installing mat specific to site conditions and purpose—results in failure of the mat, thus erosion occurs.

Mat exposed by erosion not repaired—results in poor establishment of vegetation and unstablized surface.

Sub-Section 3.2

RUNOFF CONTROL

3.21 Temporary Diversion

3.22 Permanent Diversion

3.23 Diversion Dike (Temporary Perimeter Protection)

3.24 Water Bar (Right-of-Way Diversion)

3.25 Rock Check Dam

3.26 Temporary Slope Drain

Practice 3.21
Temporary Diversion

Purpose
(Exhibit 3.21-A)

* To protect work areas from runoff and divert water to sediment traps or stable outlets.

Exhibit 3.21-A. A temporary earthen diversion.

Requirements
(Exhibit 3.21-B)

Contributing drainage area: 3 acres maximum.
Capacity: Peak runoff from a 2-yr. frequency, 24-hr. duration storm event.
Ridge: Side slopes—2:1 or flatter (3:1 or flatter if mowed); top width—2 ft. minimum; freeboard—4 in. minimum.
Channel: Shape—parabolic, trapezoidal, or V-shaped; side slopes—2:1 or flatter (3:1 or flatter if mowed).
Grade: Stable, positive towards outlet, but not exceeding 1%.
Outlet: Non-erosive for design flow; flow containing sediment diverted to sediment trap or basin.
Stabilization: Ridge stabilized if in place more than 30 working days; channel stabilized for design flow.

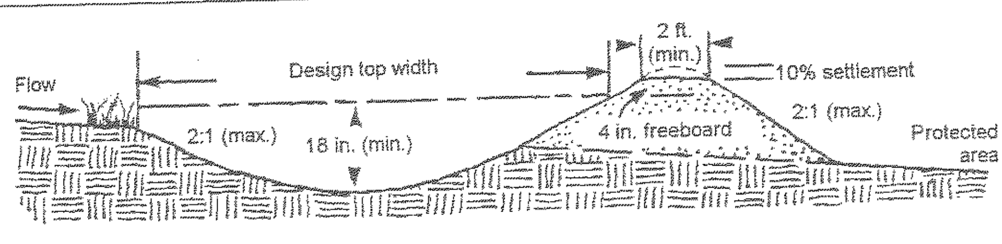


Exhibit 3.21-B. Cross-section view of a temporary diversion.

Installation

SITE PREPARATION:
1. Mark diversion location.
2. Remove trees, brush, stumps, and other debris from site.
3. Set grade and alignment to fit site needs and topography, maintaining a stable, positive grade towards outlet, and realigning or elevating the ridge as needed to avoid reverse grade.

CONSTRUCTION:

1. Construct the diversion to dimensions and grades shown in *Exhibit 3.21-B*.
2. Build the ridge higher than designed, and compact with wheels of the construction equipment. (The compacted ridge must be at or above design grade at all points, while the channel must be at design grade.)
3. Leave sufficient area along the diversion to permit clean-out and re-grading.
4. Stabilize the outlets during construction of the diversion. (Flow containing sediment must be diverted to a sediment trap.)
5. If the diversion is constructed above a steep slope, use temporary slope drains for outlets (Practice 3.33).

STABILIZATION:

1. Vegetate and mulch the ridge immediately after construction, unless the diversion will be in place less than 30 working days.

Maintenance

* Inspect weekly and following each storm event.
* Remove sediment from the channel and reinforce the ridge as needed.
* Check outlets and make necessary repairs immediately.
* Remove sediment from traps when they are 50% full.
* When the work area has been stabilized, remove the ridge, fill the channel to blend with the natural ground, remove temporary slope drains, and stabilize all disturbed areas.

Common concerns

Sedimentation where channel grade decreases or reverses—results in overtopping; realign or deepen the channel to maintain grade.

Low point in ridge where the diversion crosses a natural depression—build up the ridge.

Vehicle crossing point—maintain the ridge height, flatten the side slopes, and protect the ridge with gravel at the crossing point.

Excessive grade in channel—results in erosion in channel; install an erosion-resistant lining, or re-align to reduce the grade (Practices 3.31 and 3.32).

Excessive velocity at outlet—install an outlet stabilization structure (Practices 3.41, 3.42, and 3.43).

Ridge not compacted—runoff from storm event may cause failure; use construction equipment to compact.

Practice 3.22
Permanent Diversion

Purpose
(Exhibit 3.22-A)

* To divert water from areas where it is in excess to locations where it can be stored, used or released without causing erosion or flood damage.

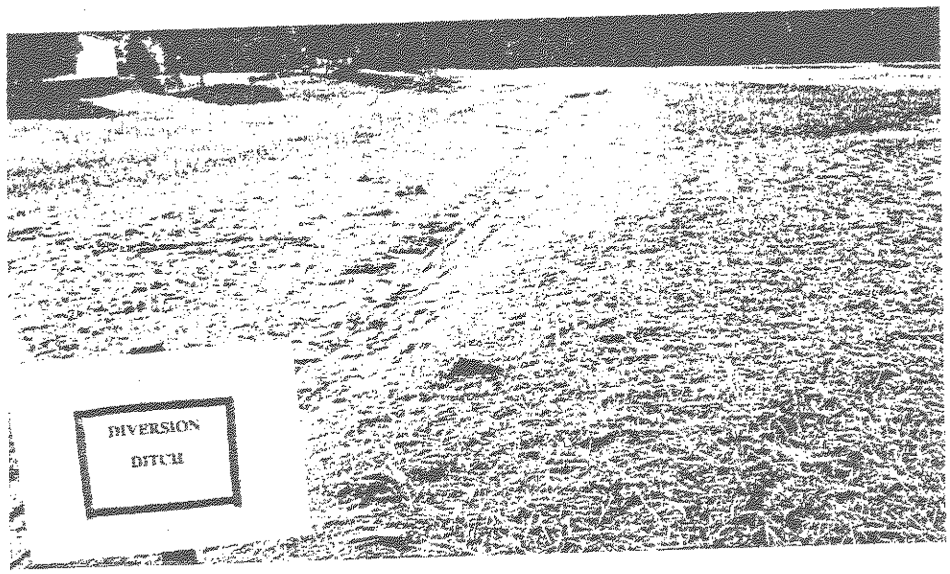


Exhibit 3.22-A. A permanent diversion sited to channel runoff without downslope erosion.

Requirements
(Exhibit 3.22-B)

Contributing drainage area: 100 acres maximum.
Capacity: Peak runoff from a 25-yr. frequency, 24-hr. duration storm event (or higher capacity where safety is a concern or flood damage cannot be tolerated).
Ridge: Side slopes—2:1 or flatter (3:1 or flatter if mowed); top width—4 ft. minimum; freeboard—6 in. minimum; settlement—6 in.; fill height—3 ft. maximum.
Channel: Lining—to meet velocity requirements and site aesthetics; side slopes—2:1 or flatter (3:1 or flatter if mowed).
Grade: Stable, positive grade towards outlet, but not exceeding 2%.
Outlet: Non-erosive for design flow.
Stabilization: Ridge and channel stabilized with vegetation or other appropriate measures.

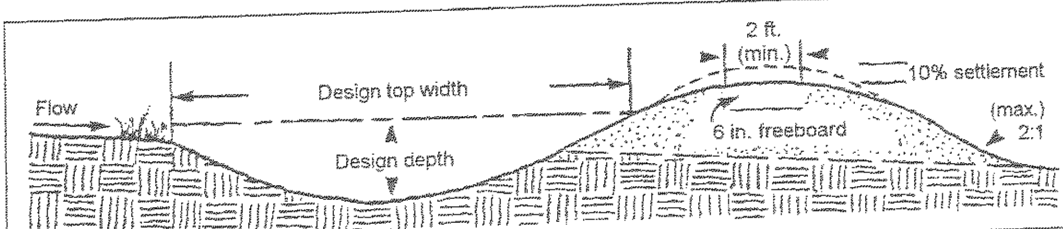


Exhibit 3.22-B. Cross-section view of a permanent diversion.

Installation

SITE PREPARATION:
1. Mark the location of the diversion.
2. Remove and properly dispose of all trees, brush, stumps, and other debris from the site.
3. Set the grade and alignment to fit site conditions, and maintain a stable, positive grade towards the outlet. Realign or elevate the ridge as needed to avoid reverse grade. (Final foundation elevation must be at or above surrounding ground level.)

4. Fill and compact all ditches, swales, or gullies to be crossed.
5. Disk the base of the ridge before placing the fill.

CONSTRUCTION:

1. Excavate, fill, shape, and stabilize the diversion to line, grade, and cross section shown in the erosion/sediment control plan (*Exhibit 3.22-B*).
2. Overfill and compact the ridge, allowing for up to 6 in. of settlement. The settled ridge top must be at or above design elevation at all points. Compaction may be achieved by driving wheel equipment along the ridge as lifts are added.
3. Shape the ridge and channel to blend with the surrounding landscape.
4. Stabilize outlets when installing diversions. Those carrying sediment from disturbed areas must empty into sediment traps or basins.
5. Stabilize the diversions immediately after installation. If vegetation is used, protect the seeding with properly anchored mulch or by installing sod (Practices 3.14, 3.31, 3.32, and 3.33).
6. Consider installing temporary slope drains until the permanent measures are established.

Maintenance

* Inspect weekly and following each storm event until the diversion is vegetated, then periodically and after major storms.
* Remove debris and sediment from the channel, and rebuild the ridge to design elevation where needed.
* Check outlets and keep in repair to prevent erosion.
* Remove sediment when sediment traps are 50% full.
* Maintain vegetation in a vigorous, healthy condition.
* When the watershed area has been stabilized, remove sediment traps and repair bare or damaged areas in the vegetation.
* Stabilize all disturbed areas.

Common concerns

Sedimentation where channel grade decreases or reverses—results in overtopping; realign or deepen the channel to maintain grade.

Low point in ridge where diversion crosses a natural depression—build up the ridge to maintain positive ridge grade.

Vehicle crossings—maintain the ridge height, flatten the side slopes, and protect the ridge with gravel at crossing points.

Erosion in channel before vegetative is fully established—install sod, or use an erosion-resistant lining to protect vegetation (Practices 3.14 and 3.31).

Erosion in channel bottom-grade too steep for vegetation—install erosion-resistant lining.

Erosion damage at outlet due to excessive velocity—install an outlet stabilization structure (Practices 3.41, 3.42, and 3.43).

Seepage or poor drainage in channel prevents establishment of vegetation—install subsurface drains or stone channel bottoms.

Practice 3.23
Diversion Dike (Temporary Perimeter Protection)

Purpose
(Exhibits 3.23-A and 3.23-B)

* To prevent storm runoff from entering and/or sediment from leaving the construction site.

Exhibit 3.23-A. A diversion or perimeter dike reduces sediment runoff leaving the construction site.

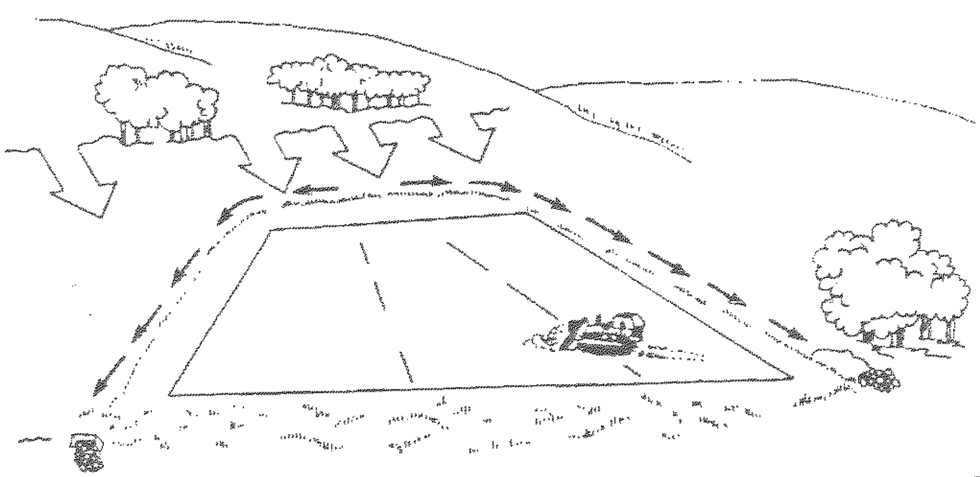


Exhibit 3.23-B. A perimeter dike can also prevent surface runoff from entering the construction site.

Requirements
(Exhibit 3.23-C)

Contributing drainage area: 5 acres maximum.
Capacity: Peak runoff from a 2-yr. frequency, 24-hr. duration storm event.
Ridge: Side slopes—2:1 or flatter (3:1 or flatter if mowed); top width—2 ft. minimum; height—1½ ft. minimum from channel bottom; freeboard—6 in. minimum; settlement—10% of fill height.
Channel: Side slopes—2:1 or flatter.
Grade: Stable, positive grade towards outlet, but not exceeding 2%.
Outlet: Stable, with sediment laden water diverted to a sediment trap or basin and runoff from undisturbed areas diverted to a stable natural outlet or outlet stabilization structure.

Stabilization: Ridge stabilized immediately after construction, and flow area stabilized according to design requirements.

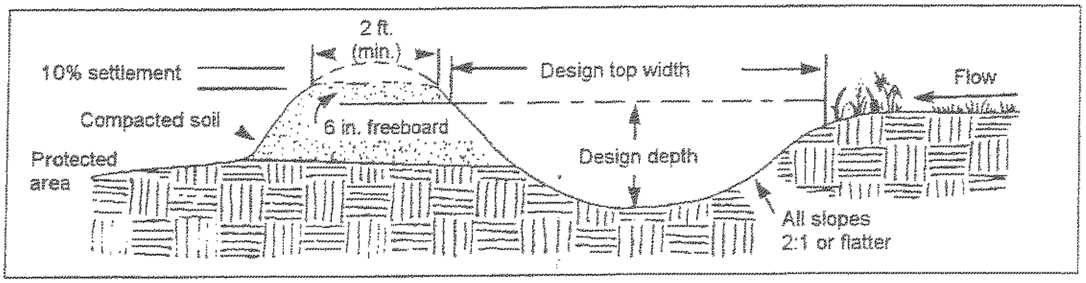


Exhibit 3.23-C. Cross-section view of a diversion or perimeter dike above an area to be protected.

Installation

SITE PREPARATION:

1. Remove all trees, brush, stumps, or other debris from the site, and dispose of properly.
2. Fill and compact all ditches or gullies to be crossed.
3. Prepare the foundation so its elevation is at or above surrounding ground level.
4. Disk the base of the dike before placing fill.

CONSTRUCTION:

1. Fill the dike higher than the design elevation, and compact with wheels of the construction equipment to design height plus 10% (see *Exhibit 3.23-C*).
2. Construct the channel to the dimensions and elevations shown on the plan.
3. Leave sufficient area along the dike to permit access by machines for cleanout and maintenance.
4. Install outlet protection and sediment traps as part of the diversion dike. (All outlets must be stable.)

STABILIZATION:

1. Stabilize the channel using erosion-resistant lining to protect vegetation, if necessary.
2. Establish vegetation on the dike immediately following construction.

* Inspect the dike periodically and after every storm event.

Maintenance

* Remove debris and sediment from the channel immediately.
* Repair the dike to its original height.
* Check outlets, and make necessary repairs to prevent gully formation.
* Clean out sediment traps when 50% full.
* Once the work area has been stabilized, remove the diversion ridge, fill and compact the channel to blend with the surrounding area, and remove the sediment traps, disposing of unstable sediment in a designated disposal area.
* Stabilize the disturbed areas.

Common concerns

Erosion in channel from excessive grade—install an erosion-resistant lining in the channel.

Overtopping caused by sediment in channel where grade decreases or reverses—deepen the channel or realign the grade.

Overtopping at low point in ridge where diversion crosses shallow draw—reconstruct the ridge with a positive grade towards the outlet at all points.

Erosion at outlet—install an outlet stabilization structure (Practices 3.41, 3.42, and 3.43).

Sedimentation at diversion outlet—install a temporary sediment trap (Practice 3.71).

CAUTION: Water diverted from the construction site must not damage adjacent property.

Practice 3.24
Water Bar (Right-of-Way Diversion)

Purpose

(Exhibits 3.24-A and B)

* To prevent erosion on long, sloping right-of-way routes by diverting runoff at selected intervals.

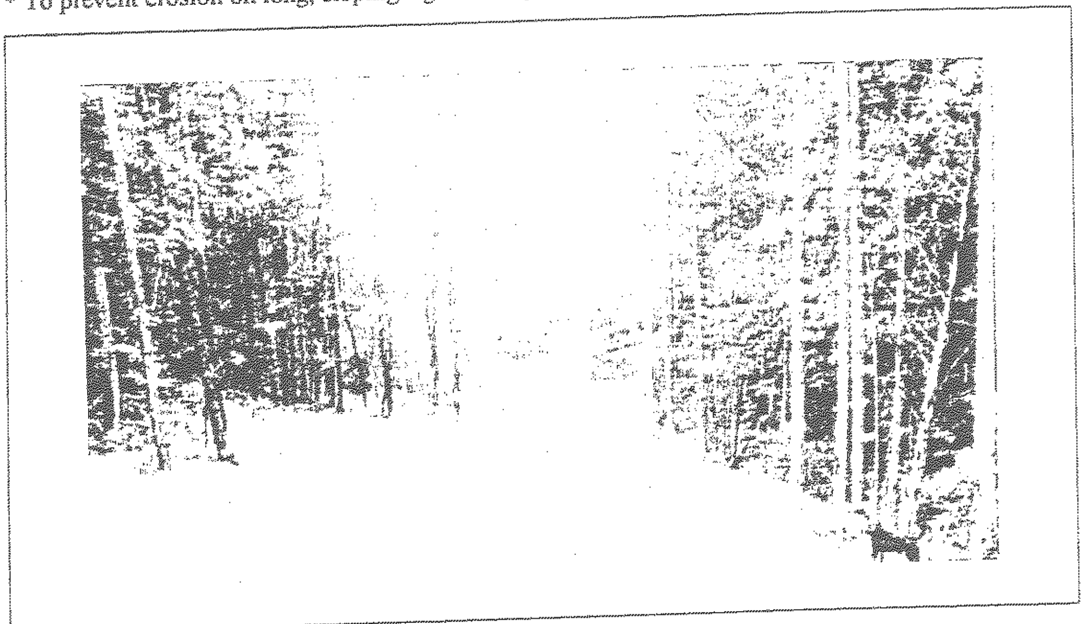


Exhibit 3.24-A. Water bars prevent erosion in utility access routes.

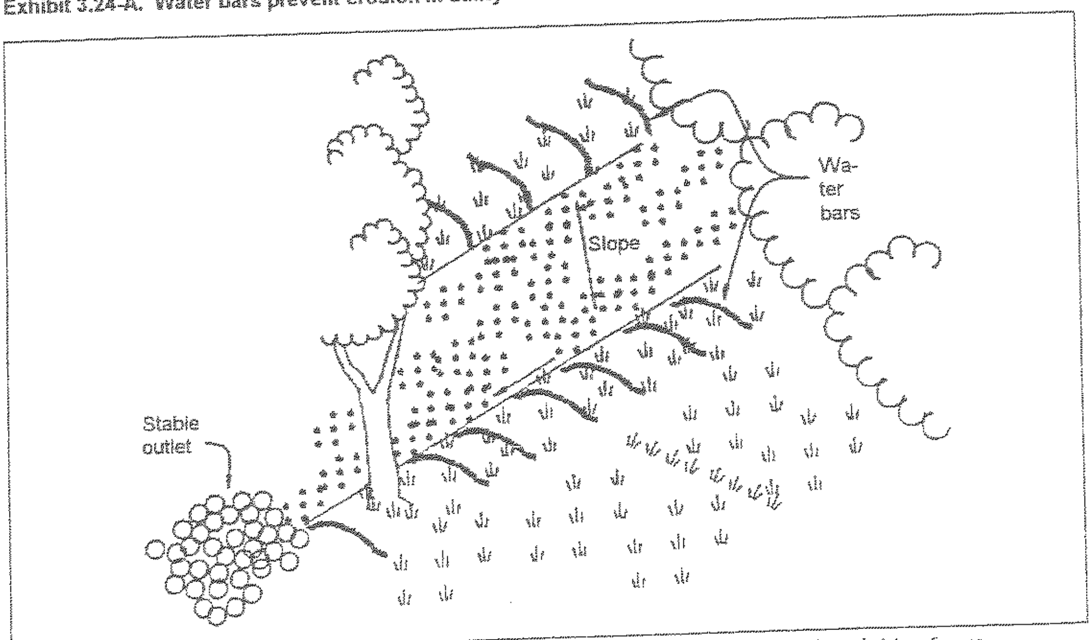


Exhibit 3.24-B. A system of water bars reduces runoff accumulation on long, sloping rights-of way.

Requirements

(Exhibits 3.24-C and D)

Right-of-way width: 100 ft. maximum.

Spacing: As shown in *Exhibit 3.24-C.*

Height: 18 in. minimum from channel bottom to top of settled ridge, 9 in. minimum from down-slope ground level to top of settled ridge.

Side slope: 2:1 or flatter.

Base width of ridge: 6 ft. minimum.

Grade: Stable, positive grade towards outlet, but not exceeding 2%.

Outlet: Water bar must cross full access width and extend to a stable outlet.

Exhibit 3.24-C. Spacing of Water Bars as Determined by Right-of-Way Slope.

Slope	Spacing
Less than 5%	125 ft.
5 to 10%	100 ft.
10 to 20%	75 ft.
20 to 35%	50 ft.

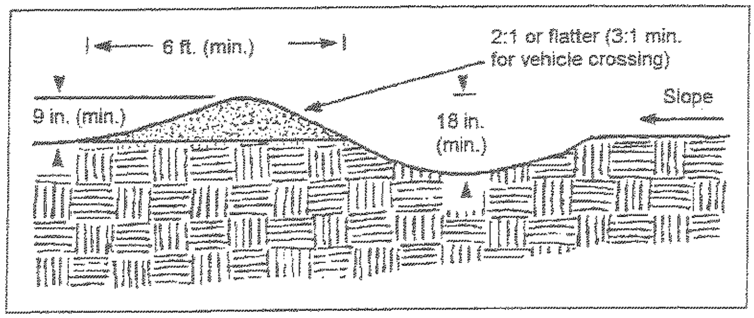


Exhibit 3-24-D. Cross-section view of a right-of-way water bar.

Installation

1. Clear and grade the access right-of-way. Set the crossing angle such as to maintain a positive grade of less than 2% (approximately 60° angle preferred).
2. Construct sediment traps or outlet stabilization structures as needed.
3. Locate the first bar at the required distance from the slope crest depending on steepness of right-of-way slope (see *Exhibit 3.24-C*).
4. Set the direction of water bars to utilize the most stable outlet locations. If necessary, adjust length of and/or spacing between bars to prevent runoff from those upslope from converging with downslope water bar outlets.
5. Mark the location and width of ridge, and disk the entire length.
6. Fill the ridge to above the design height, then compact with wheeled equipment down to the design height.
7. Stabilize the ridge and channel immediately following construction.

Maintenance

* Inspect water bars after storm events for erosion and sediment deposition and periodically for vehicle wear.
* Remove debris and sediment from channels and sediment traps or basins, and repair ridges to grade and planned height.
* Add gravel at crossing areas, and stabilize outlets as needed.
* Repair and stabilize water bars immediately after installation of additional utilities in the right-of-way.
* To remove temporary water bars, grade the ridge and channel to blend with the natural ground, compact the channel fill, and stabilize disturbed areas. (Do not remove water bars until all disturbed areas draining to them are stabilized.)

Common concerns

Water overtops ridge where water bar crosses low areas—construct the water bars to planned grade at all points.

Gully erosion between water bars—spacing is too wide for slope; install additional bars.

Ridge worn down and channel filled where vehicles cross—surface is not stable or side slopes are too steep, so may need gravel.

Erosion at outlets—install an outlet stabilization structure, or extend the upslope bars so runoff will not converge on the lower outlets.

Erosion in channel—grade is too steep, so realign the water bar.

Practice 3.25
Rock Check Dam

Purpose
(Exhibit 3.25-A)

* To reduce erosion in a drainage channel by slowing velocity of flow. (Check dams are commonly used (a) in channels that are degrading but where permanent stabilization is impractical due to their short period of usefulness and (b) in eroding channels where construction delays or weather conditions prevent timely installation of erosion resistant linings. Do not use check dams in perennial streams.)

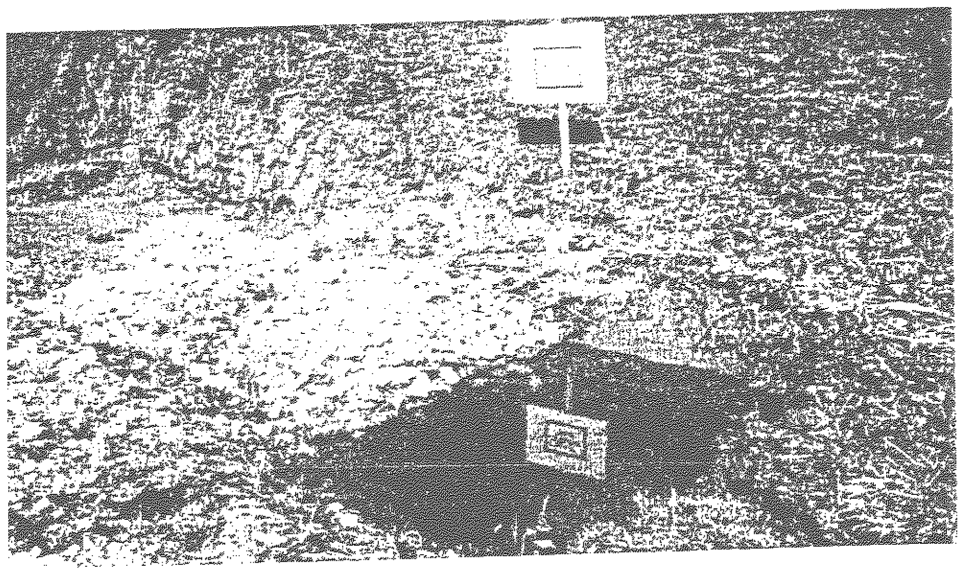


Exhibit 3.25-A. A rock check dam with a small sediment trap in a channel.

Requirements
(Exhibits 3.25-B and C)

Contributing drainage area: 2 acres maximum.
Dam center: 2 ft. maximum height but at least 9 in. lower than the outer edges at natural ground elevation.
Dam side slope: 2:1 or flatter.
Distance between dams: Spaced so the toe of the upstream dam is the same elevation as the top of the downstream dam.
Overflow areas along channel: Stabilized to resist erosion.
Rock size: INDOT Revetment Riprap.

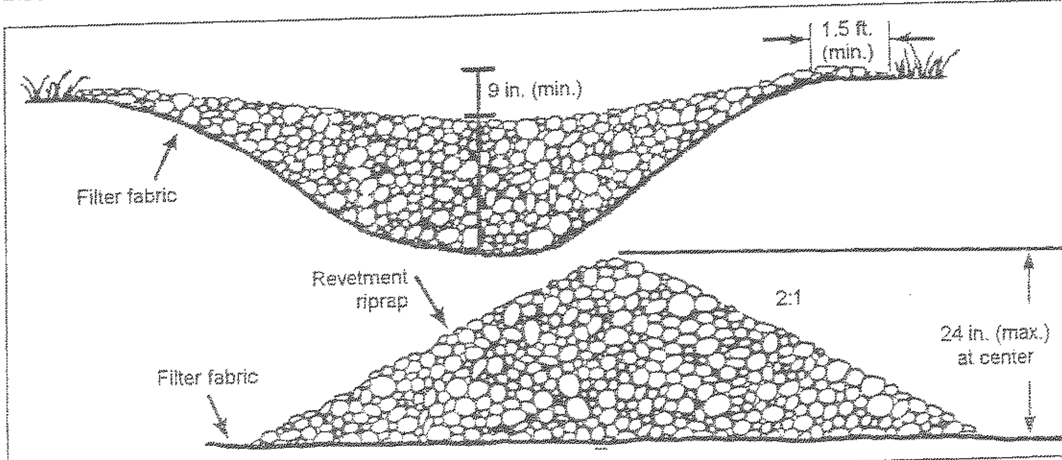


Exhibit 3.25-B. Forward and cross-section views of a rock check dam.

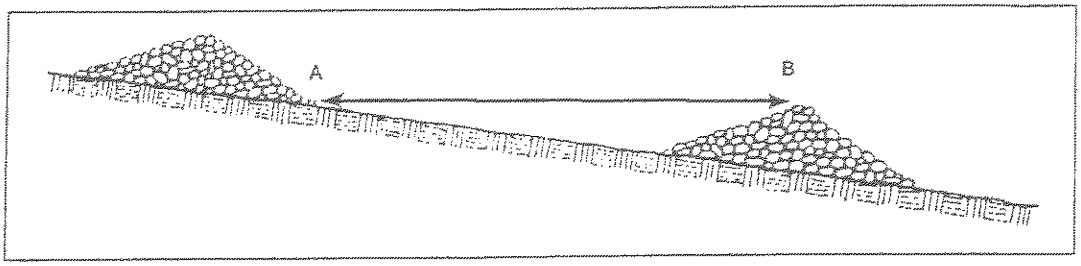


Exhibit 3.25-C. Space check dams in the channel so the up-stream dam toe elevation (A) and down-stream dam top elevation (B) are the same.

Installation

1. Excavate a cutoff trench into the ditch banks, and extend it a minimum of 18 in. beyond the abutments.
2. Place the rock in the cutoff trench and channel to the lines and dimensions shown in *Exhibit 3.25-B*—i.e., center a maximum of 2 ft. high yet 9 in. below where the dam abuts the channel banks.
3. Extend the rock at least 18 in. beyond the channel banks to keep overflow water from undercutting the dam as it re-enters the channel.
4. Install as many dams as necessary to satisfy the spacing requirement shown in *Exhibit 3.25-C*.
5. Stabilize the channel above the uppermost dam.
6. Recognizing that water will flow over and around the lowermost dam, protect the channel downstream from it with an erosion-resistant lining for a distance of 6 ft. unless the channel is protected through other means.

Maintenance

* Inspect check dams and the channel after each storm event, and repair any damage immediately.
* If significant erosion occurs between dams, install a riprap liner in that portion of the channel (Practice 3.32).
* Remove sediment accumulated behind each dam as needed to maintain channel capacity, to allow drainage through the dam, and to prevent large flows from displacing sediment.
* Add rock to the dams as needed to maintain design height and cross section.
* When the dams are no longer needed, remove the rock and stabilize channel, using an erosion-resistant lining if necessary.

Rocks washed out—results in channel cutting; repair the washes and replace the rock.

Common concerns

Dam too high—water flow erodes around the rock; to correct, remove the rock, extend the dam into the channel bank, then replace the rock.

Practice 3.26
Temporary Slope Drain

Purpose
(Exhibit 3.26-A)

* To convey runoff water down the face of a cut or fill slope without causing erosion.

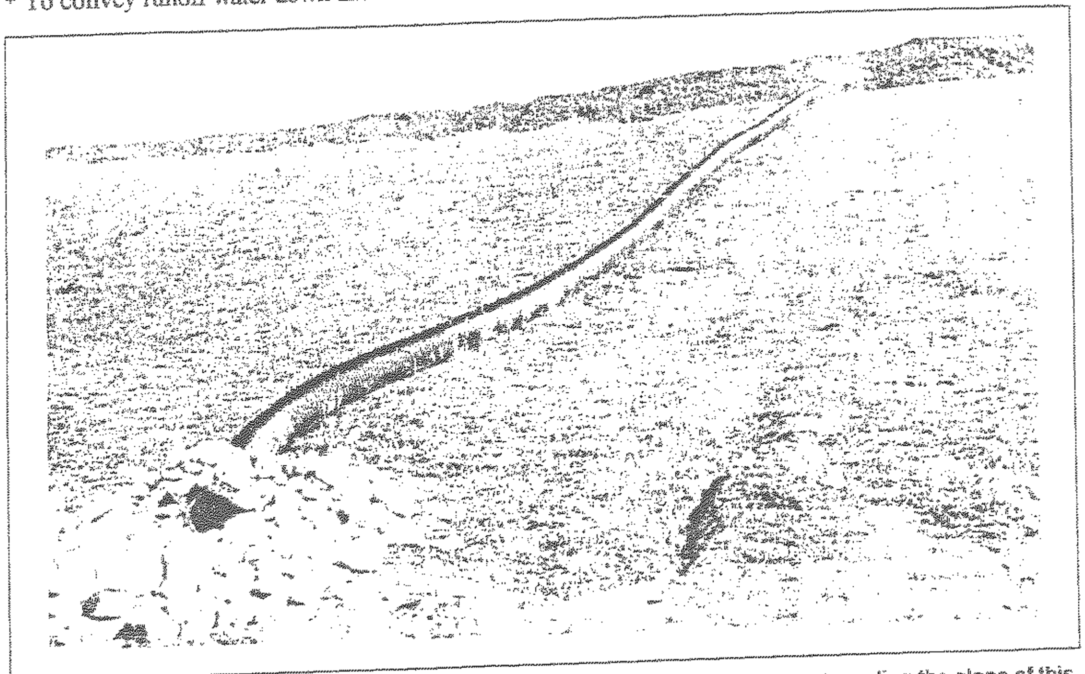


Exhibit 3.26-A. A temporary slope drain conveys runoff to a lower elevation without eroding the slope of this landfill. The pipe should be anchored with stakes to prevent it from moving.

Requirements
(Exhibits 3.26-B, C, and D)

Capacity: Peak runoff from 2-yr. frequency, 24-hr. duration storm event.
Pipe size: Based on drainage area as shown in *Exhibit 3.26-B).*
Material: Strong, flexible pipe, such as heavy-duty, non-perforated, corrugated plastic.
Inlet section: Standard "T" or "L" flared-end section with metal toe plate.
Connection to ridge at top of slope: Compacted fill over pipe with minimum dimensions, 1½-ft. depth, 4-ft. top width, and 6-in. higher than ridge.
Outlet: Pipe extends beyond toe of slope, and discharges into a sediment trap or basin unless contributing drainage area is stable.

Exhibit 3.26-B. Pipe Size for a Temporary Slope Drain.

Max. drainage area per pipe	Min. pipe diameter
0.5 acre	8 in.
0.75 acre	10 in.
1.0 acre	12 in.
Greater than 1.0 acre	Individually designed

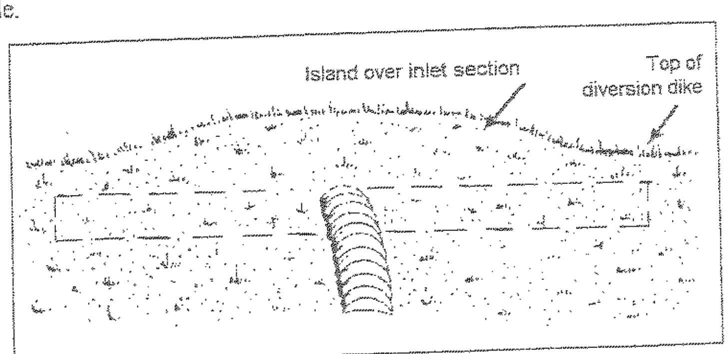


Exhibit 3.26-C. Slope drain should have a compacted fill island to prevent overtopping and diversion dike to direct runoff to the drain pipe.

Installation

1. Place temporary slope drains on undisturbed soil or well-compacted fill.
2. Set the slope drain inlet at the bottom of the diversion channels.
3. Connect the pipe to the inlet section.
4. Construct the diversion ridge by placing fill over the pipe in 6 in. lifts.

5. Compact each lift by hand-tamping under and around the inlet and along the pipe. (*Caution:* Excessive compacting may displace or collapse the pipe.)
6. Repeat Steps 4 and 5 until the minimum depth, width, and side slope dimensions shown in *Exhibit 3.26-D* are reached. Making the top of the fill 6 in. higher than the adjoining diversion ridge creates an island over the pipe to prevent overtopping (see *Exhibit 3.26-C*).
7. Make all pipe connections watertight and secure so that joints will not separate in use.
8. Anchor the pipe to the face of the slope with stakes spaced no more than 10 ft. apart (see *Exhibit 3.26-D*).
9. Extend the drain beyond the toe of the slope to a stable grade, and protect the outlet from erosion. (Terminate the drain in a 4-ft. level section, if possible.)
10. Grade the diversion channel at the top of the slope toward the temporary slope drain. A stable, positive grade not exceeding 2% is needed.
11. Stabilize all disturbed areas following installation.

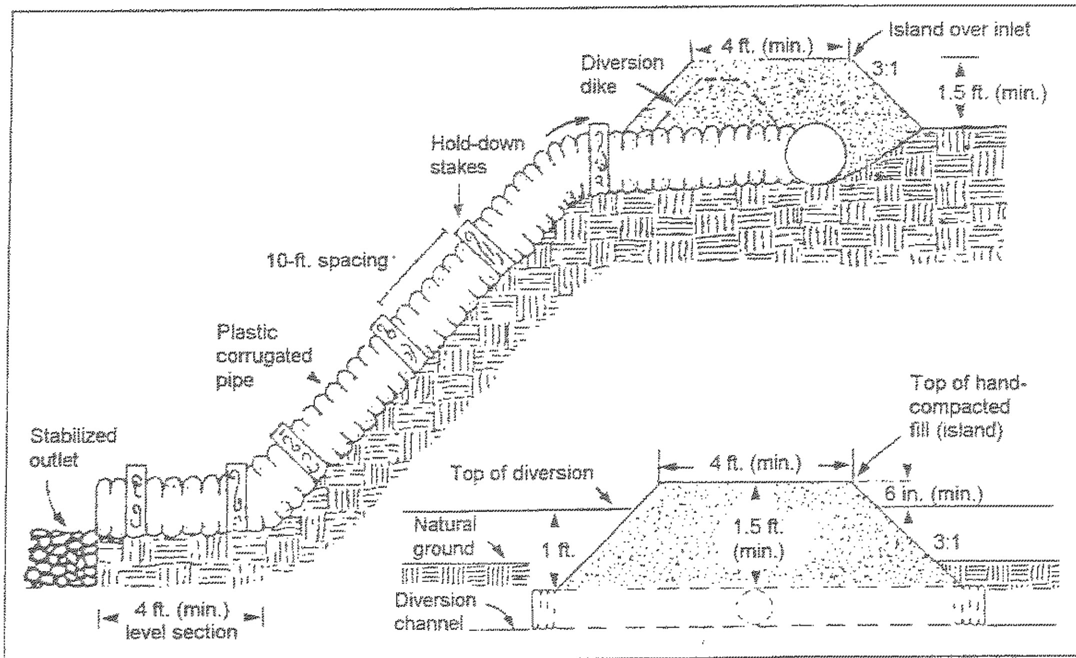


Exhibit 3.26-D. Cross-section view of a temporary slope drain, with detail of inlet.

Maintenance

* Inspect slope drains and supporting diversions once a week and after every storm event.
* Check the inlet for sediment or trash accumulation; clear and restore to proper entrance condition.
* Check the fill over the pipe for settlement, cracking, or piping holes; repair immediately.
* Check for holes where the pipe emerges from the dike; repair immediately.
* Check the conduit for evidence of leaks or inadequate anchoring; repair immediately.
* Check the outlet for erosion or sedimentation; clean and repair, or extend if necessary.
* Once slopes have been stabilized, remove the temporary diversions and slope drains, and stabilize all disturbed areas.

Common concerns

Washout along pipe due to seepage and piping—inadequate compaction, insufficient fill, or installation is too close to the edge of the slope.

Overtopping caused by undersized or blocked pipe—drainage area may be too large.

Overtopping caused by improper grade of channel and ridge—maintain a positive grade.

Overtopping due to poor entrance conditions and trash buildup at pipe inlet—deepen and widen the channel at the pipe entrance; inspect and clear inlet frequently.

Erosion at outlet—the pipe should be extended to a stable grade or an outlet stabilization structure is needed (Practice 3.41).

Displacement or separation of pipe—tie the pipe down, and secure the joints.

Sub-Section 3.3

RUNOFF CONVEYANCES

3.31 Grass-Lined Channel

3.32 Riprap-Lined Channel

Practice 3.31
Grass-Lined Channel

Purpose
(Exhibit 3.31-A)

* To carry concentrated runoff from a small watershed area to a stable outlet without damage from erosion or flooding.

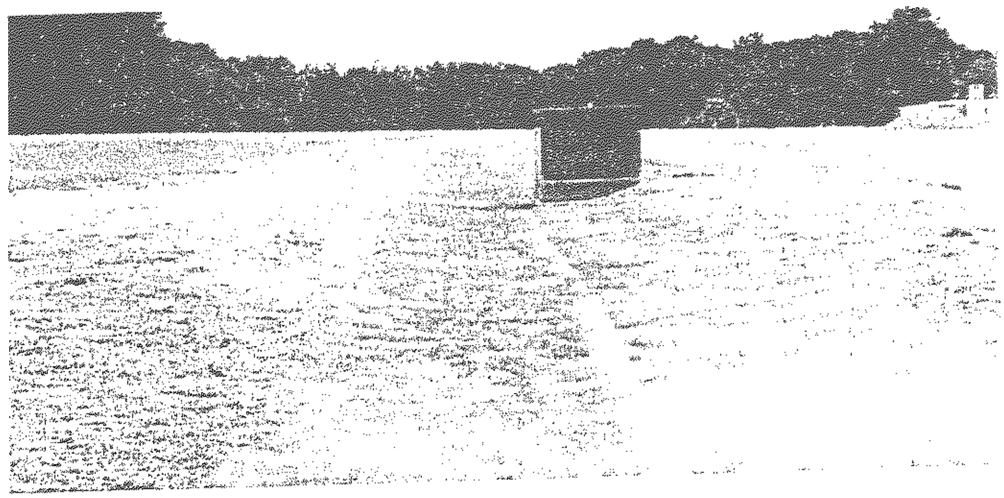


Exhibit 3.31-A. Erosion control blankets provide the bed for this grass-lined channel; however, the utility box is poorly located.

Requirements
(Exhibit 3.31-B)

Capacity: Peak runoff from 10-yr. frequency, 24-hr. duration storm event.
Cross section: Parabolic or trapezoidal.
Grade: Generally restricted to slopes 5% or less.
Side slopes: Generally 3:1 or flatter to establish and maintain vegetation and facilitate mowing.
Channel size: As specified in construction plans.
Channel stabilization: Through use of erosion control blankets, turf reinforcement mats (Practices 3.17 and 3.18) or other appropriate practices. NOTE: Unanchored mulch is generally not effective in stabilizing channels with concentrated flow (see *Exhibit 3.31-B*).
Outlet: Stable; channels carrying sediment should empty into sediment traps or basins.
Drainage tile: May be needed if channel is in an area having a seasonal high water table or seepage problems.

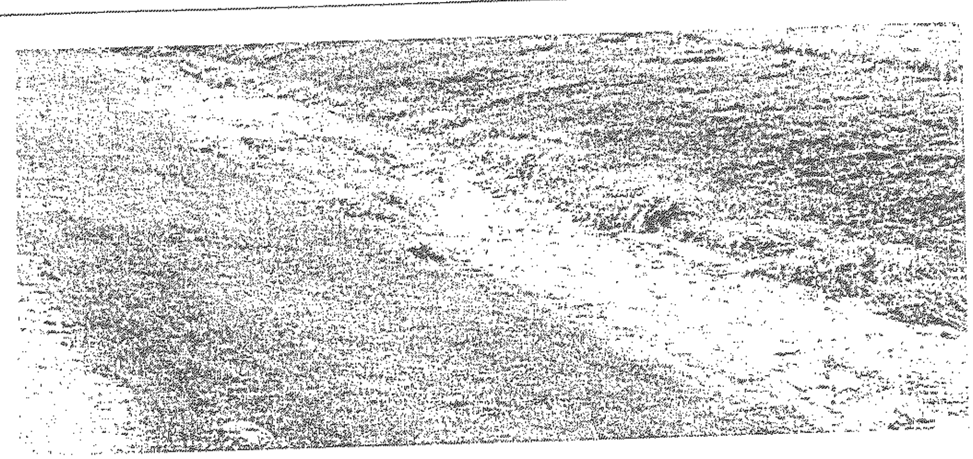


Exhibit 3.31-B. Because the straw mulch was not anchored in this channel, erosion and cutting occurred.

Installation
(Exhibit 3.31-C)

1. Install sediment traps or basins in contributing drainage area if needed (Practices 3.71, 3.72).
2. Remove brush, trees, and other debris from the foundation area and dispose of properly.
3. Excavate and shape the channel to dimensions shown on the design, removing and properly disposing of excess soil so that surface water can enter the channel freely.
4. If drainage tile is needed, install it offset to one side of the channel, not in the center. (Neither should utility lines be installed near the channel bottoms.)
5. Protect all concentrated inflow points along the channel with erosion-resistant linings, riprap, sod, or other appropriate measures.
6. Add topsoil where the soils exposed during excavation would be unsuitable for grass species.
7. Seed or sod the channel immediately after grading (Practice 3.12), and protect with erosion control blankets or turf reinforcement mats (Practices 3.17 and 3.18) (see *Exhibit 3.31-C*).
8. Stabilize outlets during channel installation (Practices 3.41, 3.42, 3.43).

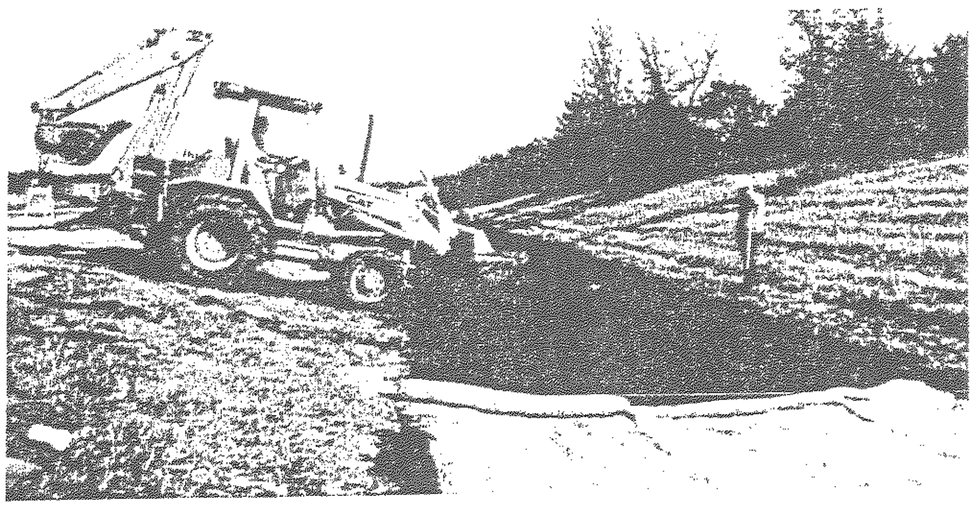


Exhibit 3.31-C. Installation of erosion control blankets in a channel next to a highway.

Maintenance

* Inspect the channel following storm events during and even after vegetative establishment; make needed repairs immediately.
* Check the channel outlet and road crossings for blockage, sediment, bank instability, and piping or scour holes; remove any blockage, and make repairs immediately.
* Remove significant sediment and debris from the channel to maintain design cross section and grade and to prevent spot erosion.

Common concerns

Erosion occurs in channel before vegetation fully established—repair, reseed, and install erosion control blankets and turf reinforcement mats (Practice 3.17 and 3.18)

Gullying or head cutting in channel—grade is too steep for a grass lining, so redesign the channel and utilize erosion-resistant lining.

Side slope caving—results from any of the following: (1) channel was dug in unstable, high-water-table soil, (2) banks are too steep for site conditions, or (3) velocity is too high, especially on the outside of channel curves.

Overbank erosion, spot erosion, channel meander, or flooding—remove accumulated debris and sediment, and stabilize and revegetate trouble spots. (Riprap or other appropriate measures may be required.)

Ponding along channel—the approach is not properly graded, or surface inlets are blocked.

Erosion at channel outlet—install an outlet stabilization structure (Practices 3.41, 3.42, 3.43).

Sediment deposited at channel outlet—indicates channel or watershed erosion. Find and repair the source of any channel erosion, stabilize the watershed, or install temporary diversions and sediment traps to protect the channel from sediment-laden runoff (Practices 3.21, 3.71, 3.72).

Gullying or settling in channel—tile was installed in the center of the channel, not off to the side.

Practice 3.32
Riprap-Lined Channel

Purpose
(Exhibit 3.32-A)

* To carry concentrated runoff from a small watershed area to a stable outlet without erosion.

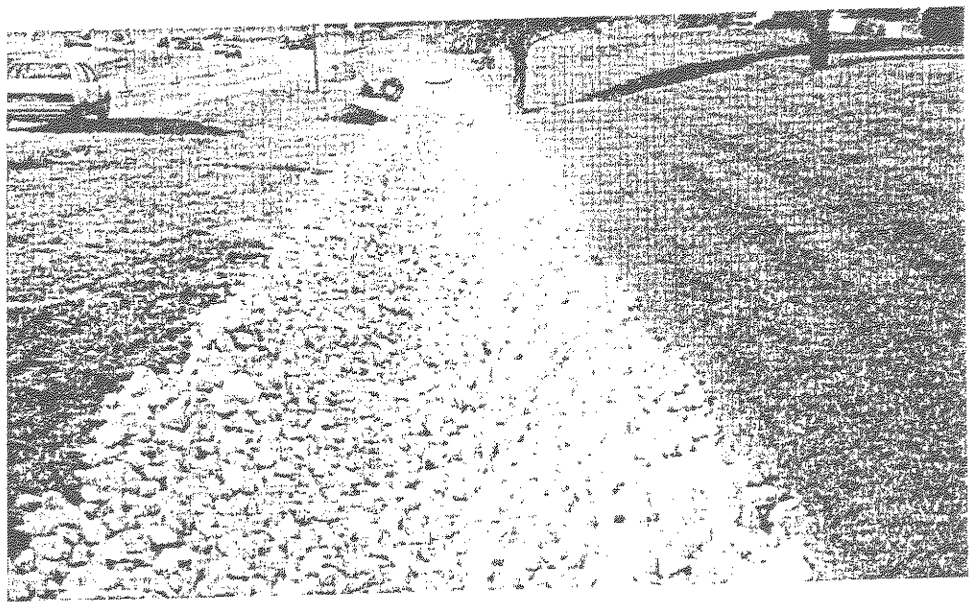


Exhibit 3.32-A. This riprap-lined channel next to a road conveys runoff downslope.

Requirements

Capacity: Peak runoff from 10-yr. frequency, 24-hr. duration storm event.
Side slopes: 2:1 or flatter.
Rock: Size and gradation as shown in design specifications. (Do not use broken concrete.)
Riprap thickness: Two times d_{50} stone diameter and a minimum of 12 in. thick.
Foundation: Geotextile fabric for filtering or aggregate (INDOT CA No. 5) filter layer under the riprap.
Channel cross section: As shown in the design specifications.
Outlet: Stable.

Installation
(Exhibits 3.32-B and C)

1. Remove brush, trees, and other debris from the channel and spoil areas, and dispose of properly.
2. Excavate cross section to the lines and grades shown in design specifications, overcutting for thickness of riprap and filter material *(Exhibit 3.32-B)*. (NOTE: This overcut significantly increases excavation and spoil disposal. For instance, for the channel in *Exhibit 3.32-B*, excavation doubles from 1.1 cu.yd./ft. of channel to 2.2 cu.yd./ft. An aggregate filter layer would require even more excavation and disposal.)
3. Install the geotextile fabric in the excavated channel as a foundation for the riprap.
4. As soon as the foundation is prepared, place the riprap to the thickness, depth and elevation shown in the erosion/sediment control plan *(Exhibit 3.32-C)*. It should form a dense, uniform, and well-graded mass with few voids. (Selective loading at the quarry and some hand placement may be necessary to obtain good distribution of rock sizes.)
5. Blend the finished rock surface with the surrounding land surface so there is no overfall or channel constriction. (Grass-lined channels with riprap bottoms must have smooth transition between riprap and vegetation.)
6. Stabilize channel inlet points, and install needed outlet protection during channel installation.
7. Stabilize disturbed areas after construction is completed.

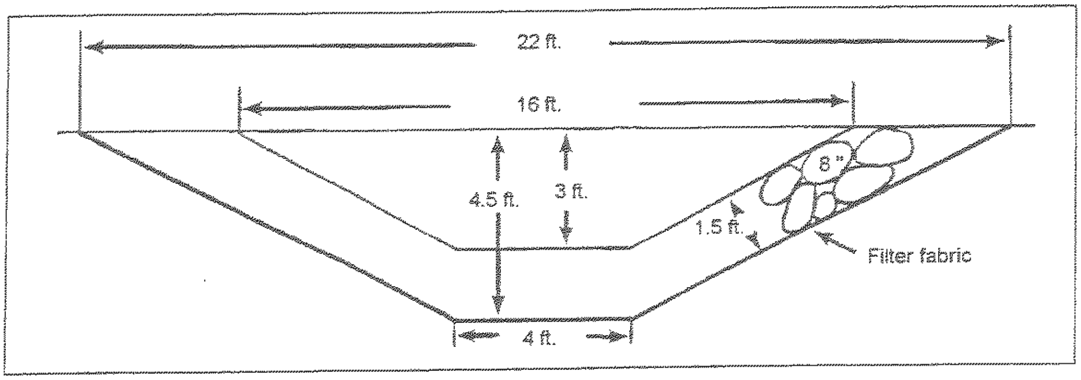


Exhibit 3.32-B. Example calculation of excavation for riprap and filter fabric in a channel. Note overcut requirements.

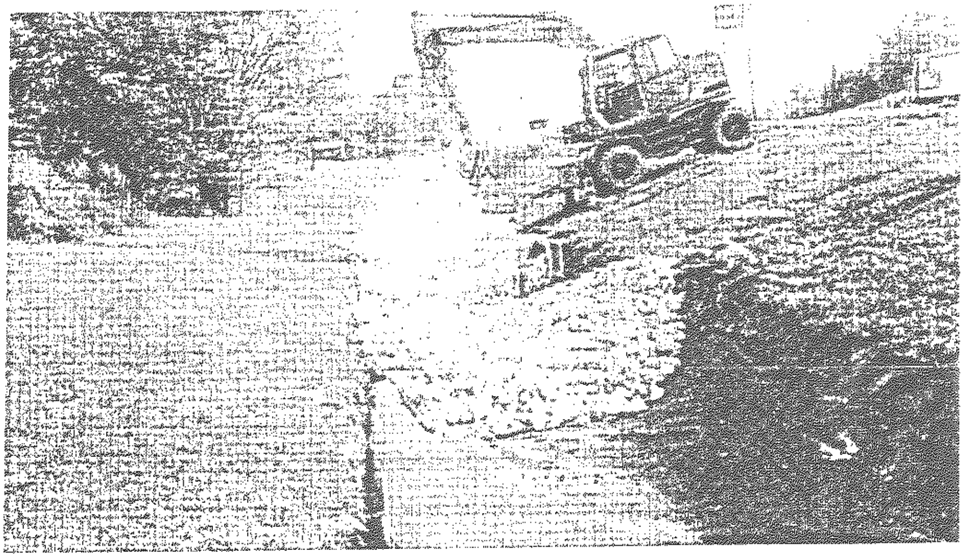


Exhibit 3.32-C. Proper installation of geotextile fabric and riprap.

Maintenance

* Inspect channels at regular intervals and after storm events.
* When stones have been displaced, remove any debris and replace the stones in such a way as to not restrict the flow area.
* Give special attention to outlets and points where concentrated flow enters the channel, and repair eroded areas promptly.
* Check for sediment accumulation, piping, bank instability, and scour holes; repair promptly.

Common concerns

Foundation not excavated deep enough or wide enough—riprap restricts channel flow, resulting in overflow and erosion.

Side slopes too steep—causes instability, rock material movement, and bank failure.

Filter omitted or damaged during stone placement—results in piping and bank instability.

Riprap poorly graded or stones not placed to form a dense, stable channel lining—results in rock material displacement and erosion of the foundation.

Riprap installed smaller than specified—results in rock displacement; selectively grouting over rock materials may stabilize the situation.

Riprap not extended far enough downstream—results in undercutting; outlet must be stable.

Riprap not blended to ground surface—results in gullying along edge of the riprap.

Riprap not utilized until washout of other materials.

Sub-Section 3.4

OUTLET PROTECTIONS

3.41 Rock Chute

3.42 Concrete Block Chute

3.43 Reinforced Vegetated

Practice 3.41
Rock Chute

Purpose
(Exhibit 3.41-A)

* To reduce runoff velocity and prevent erosion at the outlet of a channel or culvert.

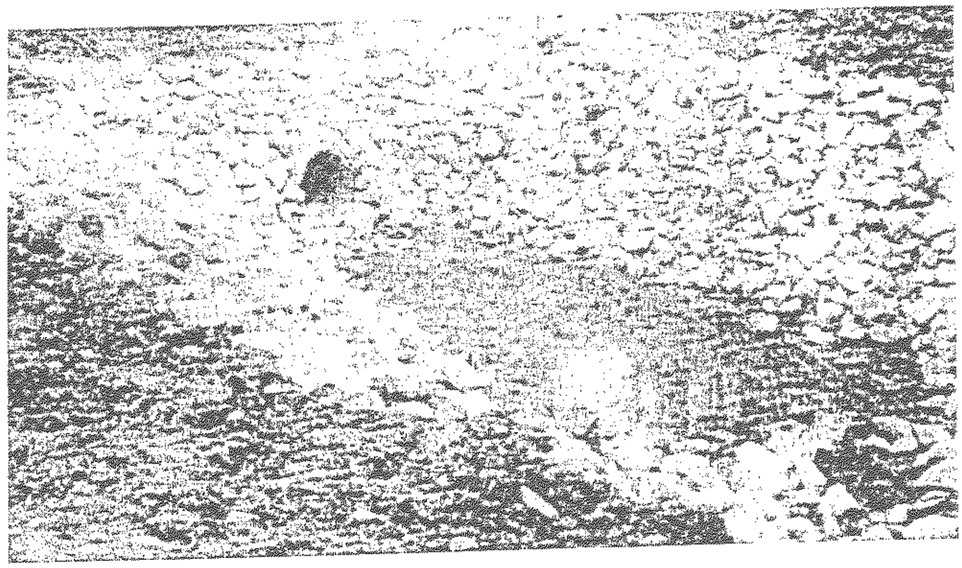


Exhibit 3.41-A. This outlet is protected by a rock chute.

Requirements
(Exhibits 3.41-B and C)

Contributing drainage area: 100 acres maximum.

Capacity: Peak runoff from 10-yr. frequency, 24-hr. duration storm event.

Apron: Design depends on channel definition (see *Exhibit 3.41-B*), but is long enough to dissipate runoff energy, set on zero grade, straight and aligned with the receiving stream. (If site conditions require a curve, set it near the upstream end.)

Foundation: Geotextile fabric for stabilization and filtration or well-graded gravel filter layer at least 6 in. thick.

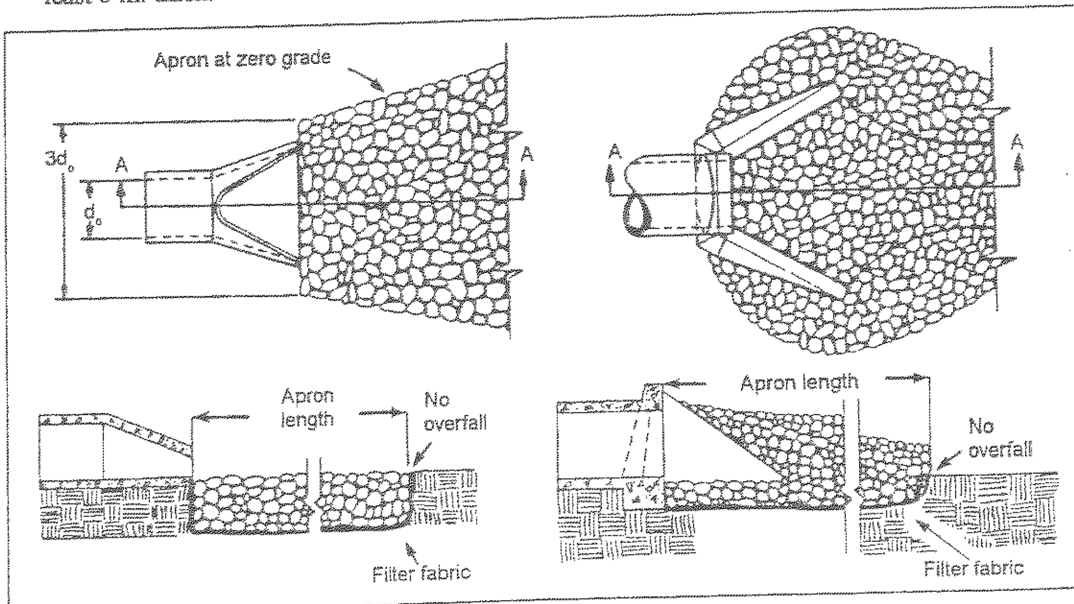


Exhibit 3.41-B. Pipe outlet aprons for a channel (left) that is not well defined and (right) that is well defined.

Material: Hard, angular, and highly weather-resistant riprap stone of size and gradation that will withstand the velocities of the chute. (Specific gravity at least 2.5; size as specified in design.)

Thickness: 12 in. minimum or two times the d_{50} stone diameter, whichever is greater.

Outlet: Stable.

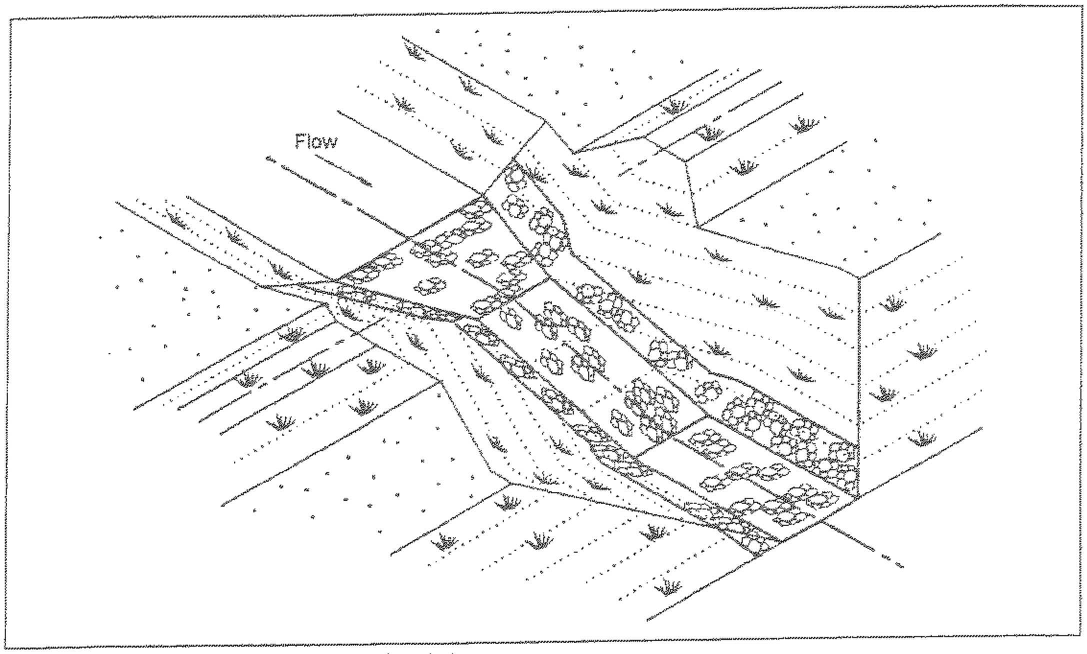


Exhibit 3.41-C. Oblique view of a rock-lined chute.

Installation

1. Excavate the apron area subgrade below design elevation to allow for thickness of the filter (or gravel layer) and the riprap. (This over-excavation greatly increases the amount of spoil.)
2. Compact any fill used in the subgrade to the density of the surrounding undisturbed material, and smooth enough to protect fabric from tearing.
3. Place the geotextile fabric (or gravel layer) on the compacted and smoothed foundation. If more than one fabric piece is needed, the upstream piece should overlap the downstream piece by at least 1 ft.
4. Install the riprap to the lines and elevations shown in the design. If the channel is poorly defined, the final cross-section should be level or slightly depressed in the middle; if well defined, the filter (or gravel layer) and riprap should extend to the top of the bank (*Exhibit 3.41-B*).
5. If the geotextile fabric tears when placing the riprap, repair immediately by laying and stapling a piece of fabric over the damaged area, overlapping the undamaged areas by at least 12 in.
6. Make sure the top of the riprap apron is level with or slightly below the receiving stream. (Riprap should not restrict the channel or produce an overfall.)
7. Blend the riprap smoothly to the surrounding grade.
8. Stabilize all disturbed areas immediately following installation.

Maintenance

* Inspect rock chutes after storm events for stone displacement and for erosion at the sides and ends of the apron.
* Make needed repairs immediately; use appropriate size stone, and do not place them above finished grade.

Common concerns

Foundation not excavated deep enough or wide enough—riprap restricts the flow cross section, resulting in erosion around the apron and scour holes at the outlet.

Riprap apron not on zero grade—may result in downstream erosion.

Riprap installed smaller than specified—results in rock displacement; selectively grouting over the rock materials may stabilize the situation.

Riprap not extended enough to reach a stable section of channel—results in downstream erosion.

No filter installed under the riprap—results in stone displacement and erosion of the foundation.

Practice 3.42
Concrete Block Chute

Purpose
(Exhibit 3.42-A)

* To reduce runoff velocity and prevent erosion at the outlet of a channel culvert or other high velocity section.

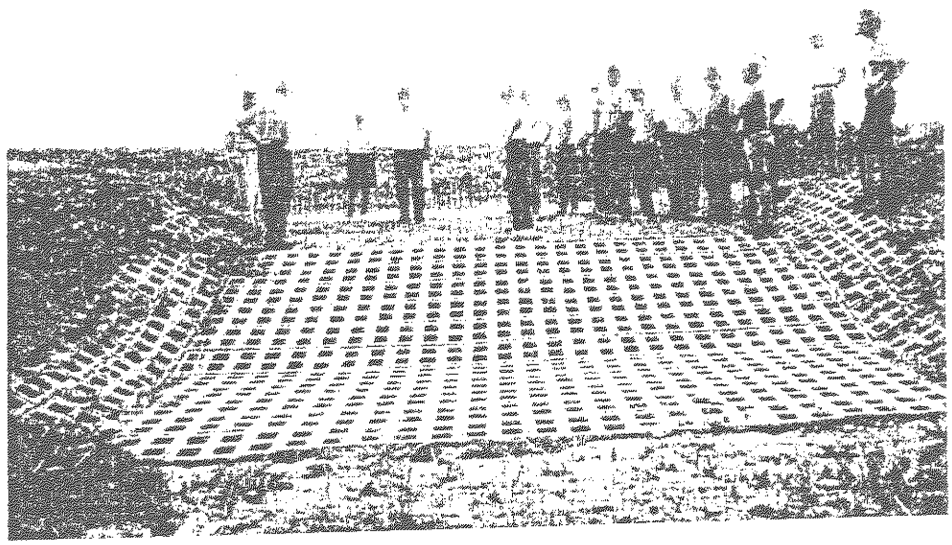


Exhibit 3.42-A. A just-constructed concrete block chute before the vegetation has been established.

Requirements
(Exhibits 3.42-B and C)

Contributing drainage area: 100 acres maximum.

Capacity: Peak runoff from a 10-yr. frequency, 24-hr. duration storm event.

Ridge: On both sides of the chute to channel runoff into the chute; side slope 2:1, with 4 ft. minimum top width.

Foundation: Chute- and side-slope subgrade excavated and/or filled and compacted to approximately 10 in. below finished grade, then overlain with plastic sheeting, 2 in. of bedding (INDOT CA No. 9, 11, or 12), and geotextile fabric.

Inlet and outlet aprons: As shown on design plan, set on zero grade, aligned straight, and excavated to 10 in.

Material: Concrete blocks, bedding (INDOT CA No. 9, 11, 12), and plastic sheeting.

Geotextile fabric: For stabilization and filtration.

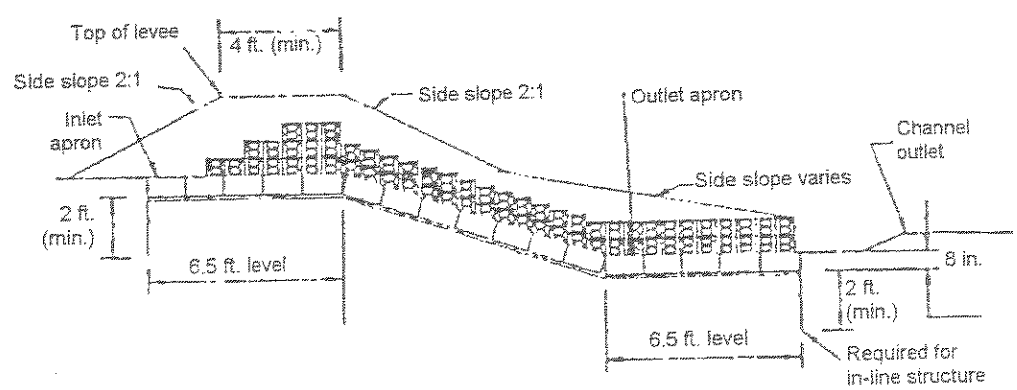


Exhibit 3.42-B. Detailed cross-sectional view of a concrete block chute.

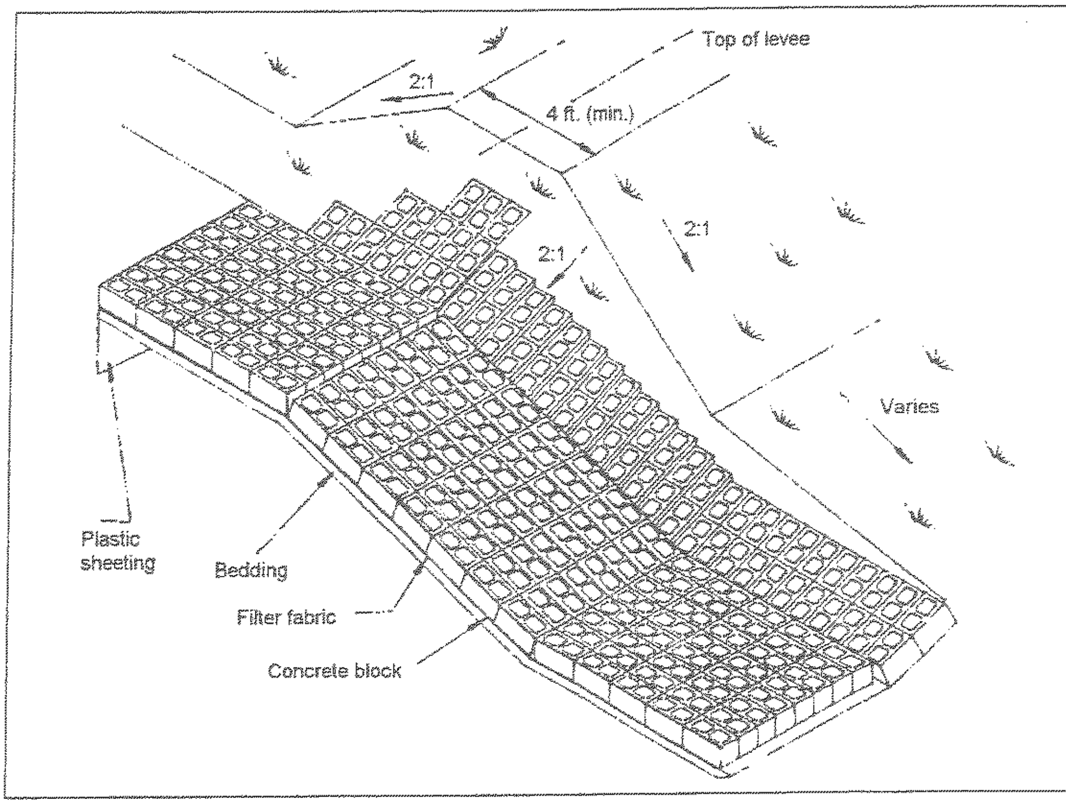


Exhibit 3.42-C. Oblique view of a concrete block chute.

Installation

1. Construct a ridge on either side of the chute.
2. Excavate chute, inlet, and outlet aprons to about 10 in. below the design plan finished grade to allow for thickness of the foundation materials and the concrete blocks. (The aprons, when installed, should be on zero grade.)
3. Compact any fill used in the subgrade to the density of the surrounding undisturbed material.
4. Smooth the subgrade enough to protect the plastic sheeting and geotextile fabric from tearing.
5. Make a small trench around the perimeter of the structure (i.e., edges of inlet and outlet aprons and top of the chute side-slopes) to secure the sheeting and fabric.
6. On the smoothed subgrade, install first the plastic sheeting, then 2 in. of sand, and finally the geotextile fabric.
7. Press the sheeting and fabric into the trench, and fill with soil to anchor.
8. Lay the concrete block (holes facing up) on the geotextile fabric as shown in *Exhibit 3.42-B*, taking care not to damage it. If it is torn when placing blocks, repair immediately by laying and stapling a piece of fabric over the damaged area, overlapping undamaged areas by 12 in.
9. Fill the holes in the blocks with soil.
10. Stabilize all disturbed areas immediately following installation.

Maintenance

* Inspect the inlet and outlet after storm events for scouring, and make repairs as needed.
* Keep the inlet and outlet areas free of any debris or other obstructions.
* Do not drive equipment or vehicles on the structure.

Common concerns

Foundation not constructed deep or wide enough—results in erosion around the inlet and scour holes at the outlet.

Outlet apron not flat—results in erosion downstream.

Filter fabric not properly anchored—results in erosion at the perimeter of the structure.

Seepage under structure—results in piping and potential collapse of the chute; to correct, install a subsurface drain to intercept seepage flow and drain it away from the structure.

Practice 3.43
Reinforced Vegetated Chute

Purpose
(Exhibit 3.43-A)

* To reduce runoff velocity and prevent erosion at the outlet of a channel, culvert, or other high-velocity section of waterway.

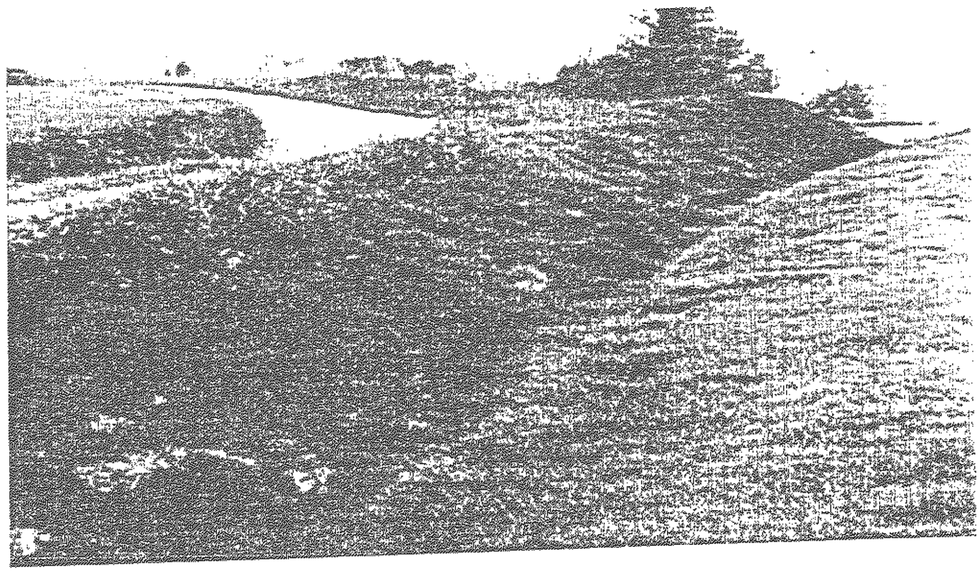


Exhibit 3.43-A. A reinforced vegetated chute utilizes erosion control blankets and turf reinforcement mats to protect a channel from erosion.

Requirements
(Exhibit 3.43-B)

Contributing drainage area: 20 acres maximum with no base flow.
Capacity: Peak runoff from a 2-yr. frequency, 24-hr. duration storm event.
Material: Erosion control blankets and turf reinforcement mats (Practices 3.17 and 3.18), with gravel or crushed stone riprap (INDOT CA No. 5) at the inlet and outlet aprons.
Tile drainage: As needed, installed as shown, using outlet pipe section with animal guard.

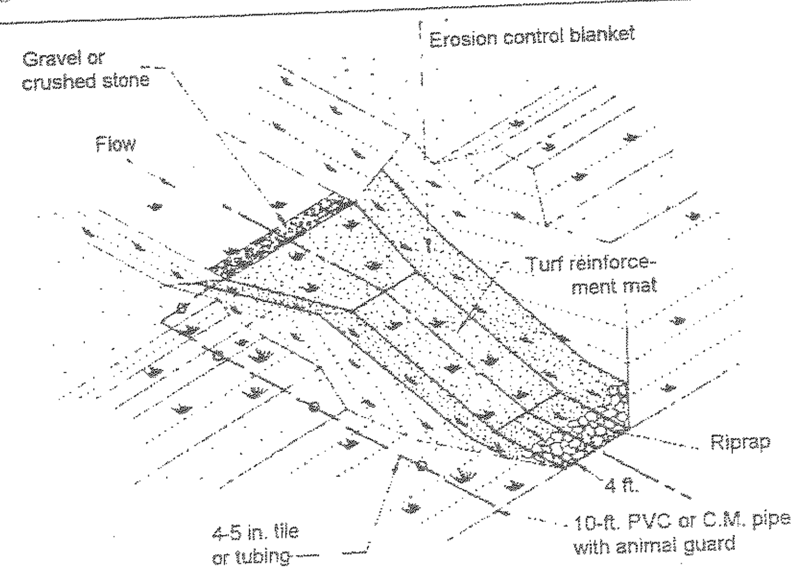


Exhibit 3.43-B. Oblique view of a reinforced vegetated chute.

Installation

1. Construct a ridge on each side of the chute to contain runoff, according to designed capacity.
2. Excavate and/or fill and compact the required section and slope to finished grade as specified in the erosion and sediment control plan.
3. Construct the inlet and outlet aprons so they are straight, aligned with the receiving channel, and at zero grade.
4. Lay drain tile outside the chute area as shown in *Exhibit 3.43-B*, including outlet pipe section and animal guard.
5. Install and anchor the turf reinforcement mat according to manufacturer's directions (Practice 3.18), and cover with soil.
6. Immediately following mat installation, permanently seed, fertilize, and install erosion control blankets according to manufacturer's directions (Practices 3.12 and 3.17).

Maintenance

* During vegetative establishment, inspect after every storm event, checking particularly for blockage, sediment and scour holes.
* Remove accumulated sediment, and make other repairs as necessary.

Common concerns

Outlet apron not flat—results in erosion downstream.

Erosion control blankets and turf reinforcement mats not properly anchored—results in loosening and displacement of materials and erosion of channel.

Chute not constructed to designed capacity—results in scouring around inlet apron, or overtopping and bypassing of chute.

Sub-Section 3.5

TEMPORARY DROP INLET PROTECTIONS

Practice 3.51
Excavated Drop Inlet Protection

Purpose
(Exhibit 3.51-A)

* To capture sediment at the approach to a storm drain inlet, allowing full use of the storm drain system during the construction period.

NOTE: This practice may be used to improve the ef-fectiveness and reliability of other sediment traps and barriers, such as fabric, block-and-gravel, slotted-barrel, straw bale, and gravel donut inlet protections.

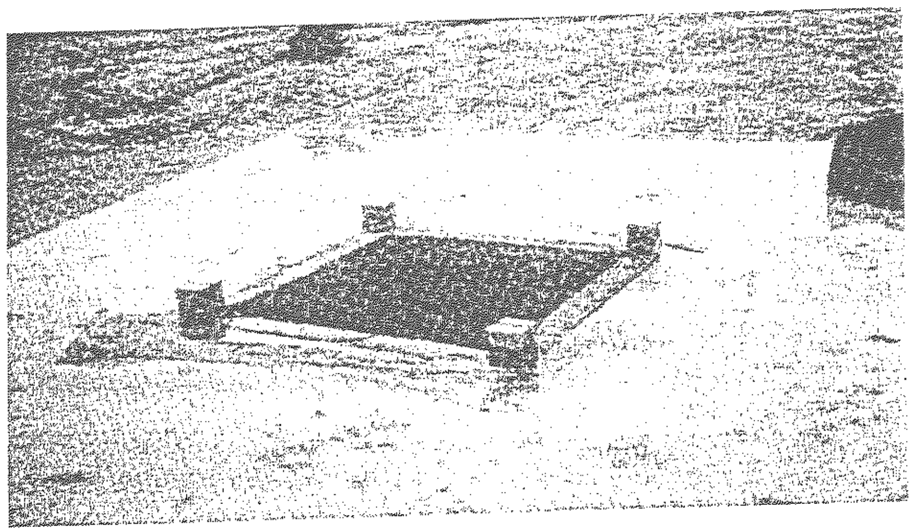


Exhibit 3.51-A An excavated drop inlet creates a pool that allows sediment to settle out as water drains.

Requirements
(Exhibit 3.51-B and C)

Contributing drainage area: 1 acre maximum.
Capacity: Runoff from a 2-yr. frequency, 24-hr. storm event entering a storm drain without by-pass flow.
Excavated depth: 1-2 ft. measured from top of inlet.
Excavated volume: Minimum of 945 cu.ft./acre disturbed.
Side slopes: 2:1 or flatter.
Dewatering system: Weep holes in the drop inlet, covered with hardware cloth and gravel.
Approach: Pool area flat (less than 1% slope), with sediment storage of 945 cu.ft./acre disturbed.

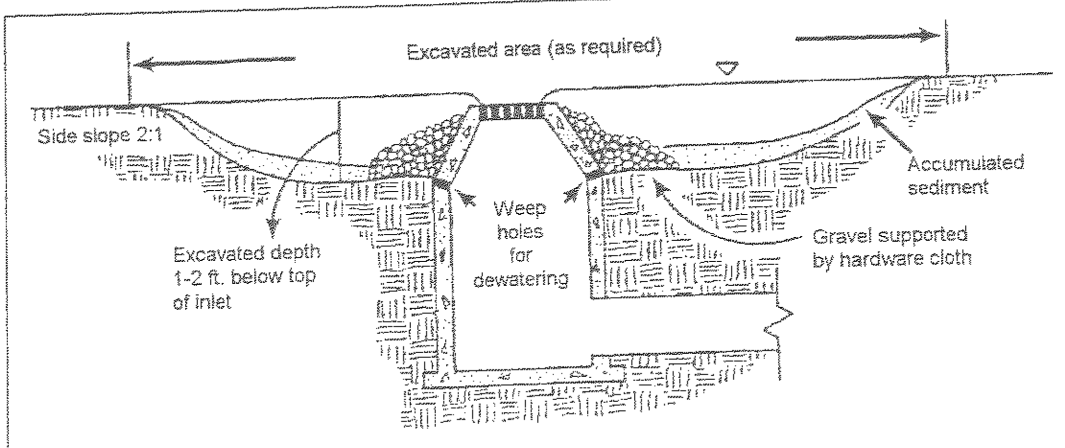


Exhibit 3.51-B. Cross-sectional view of an excavated drop inlet protection.

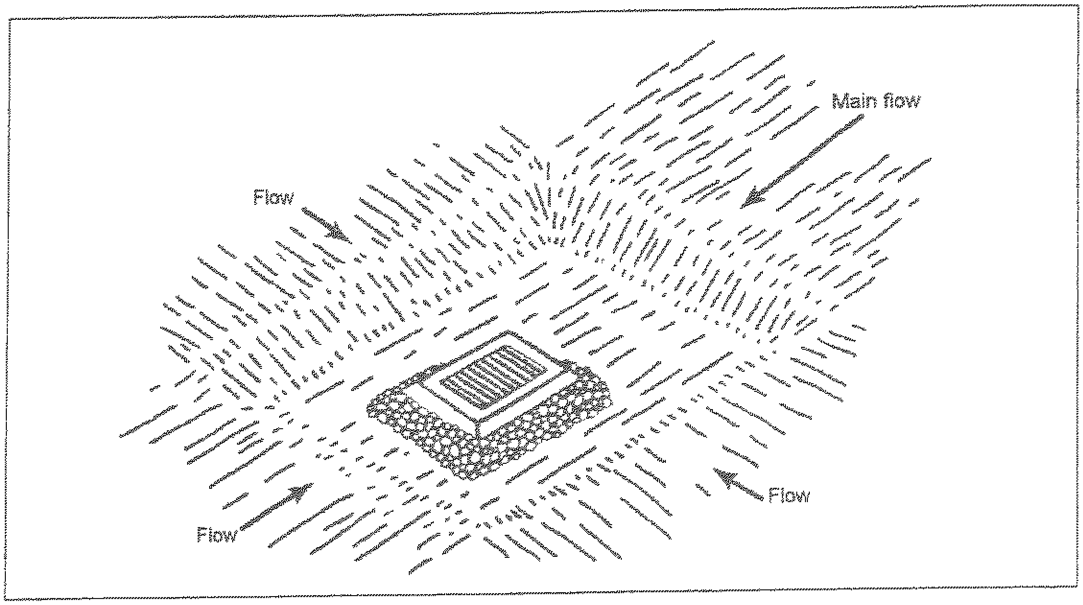


Exhibit 3.51-C. Perspective view of an excavated drop inlet protection.

Installation

1. Clear the area of all debris.
2. Excavate the basin to a 1-2 ft. depth, with 2:1 maximum side slopes and the longest dimension oriented toward the largest inflow (see *Exhibits 3.51-B and 3.51-C*).
3. Stockpile or spread the excavated soil so it will not block the flow or wash back into the excavation.
4. Install weep holes in the drop inlet so the pool drains slowly.
5. Cover the weep holes with hardware cloth and at least 1 ft. of gravel (INDOT CA No. 5) to retain the sediment (see *Exhibit 3.51-C*).
6. If necessary, spoil may be placed to form a dike on the downslope side of the excavation to prevent bypass flow.
7. Stabilize all disturbed areas, except the excavated pool bottom.

Maintenance

* Inspect the excavated basin after every storm event, and repair as necessary until the contributing drainage area has been permanently stabilized.
* Remove sediment when the basin is approximately half full of sediment.
* Remove and replace gravel over the weep holes when drainage stops.
* Once the contributing drainage area has been permanently stabilized, seal the weep holes, remove the sediment, fill the basin with soil, compact and grade to final elevation, and stabilize.

Common concerns

Sediment fills excavated basin and enters storm drain—the sediment-producing area is too large for the basin design or the inlet is not properly maintained.

Excessive ponding—gravel over the weep holes may be plugged with sediment; to correct, remove the debris, clear the sediment, and replace the gravel.

Practice 3.52
Fabric Drop Inlet Protection

Purpose
(Exhibit 3.52-A)

* To capture sediment at the entrance to a storm drain, allowing full use of the storm drain system during the construction period.

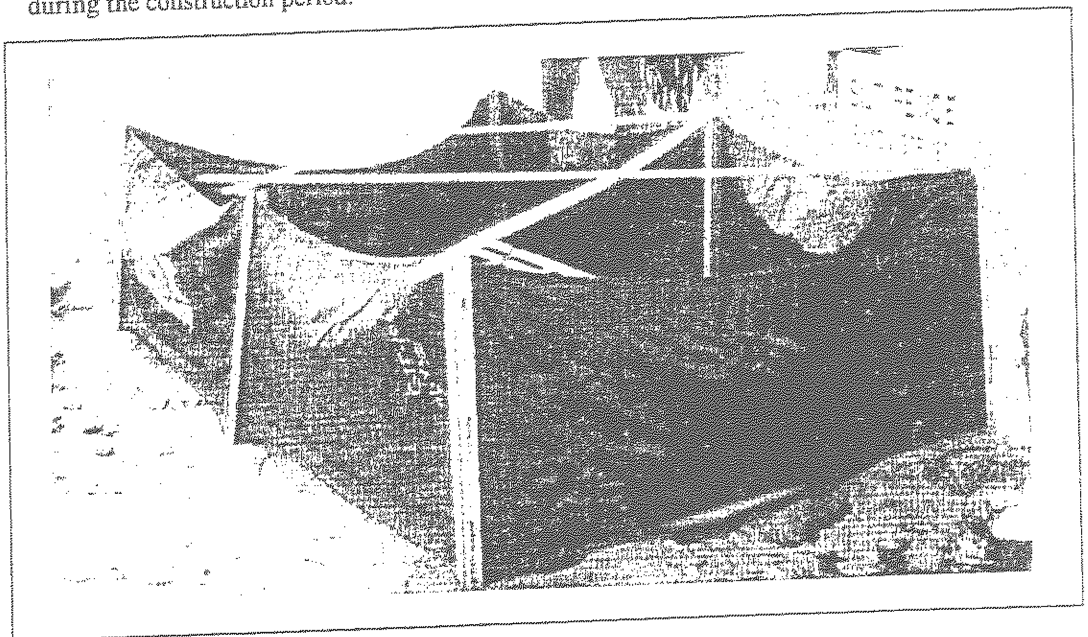


Exhibit 3.52-A. A fabric drop inlet protection.

Requirements
(Exhibits 3.52-B)

Contributing drainage area: 1 acre maximum.
Capacity: Runoff from a 2-yr. frequency, 24-hr. duration storm event entering a storm drain without bypass flow.
Fabric material: Geotextile fabric for filtration.
Height of fabric: 1 to 1½ ft., measured from top of inlet.
Approach: Pool area flat (less than 1% slope) with sediment storage of 945 cu.ft./acre disturbed.
Stability: Structure must withstand 1½ ft. head of water and sediment without collapsing or undercutting.
Support posts: Steel fence posts or 2 x 2-in. or 2 x 4-in. hard wood posts, 3 ft. minimum length, 3 ft. maximum spacing; top frame support recommended. Cross bracing tops of posts to opposite corners greatly strengthens support.

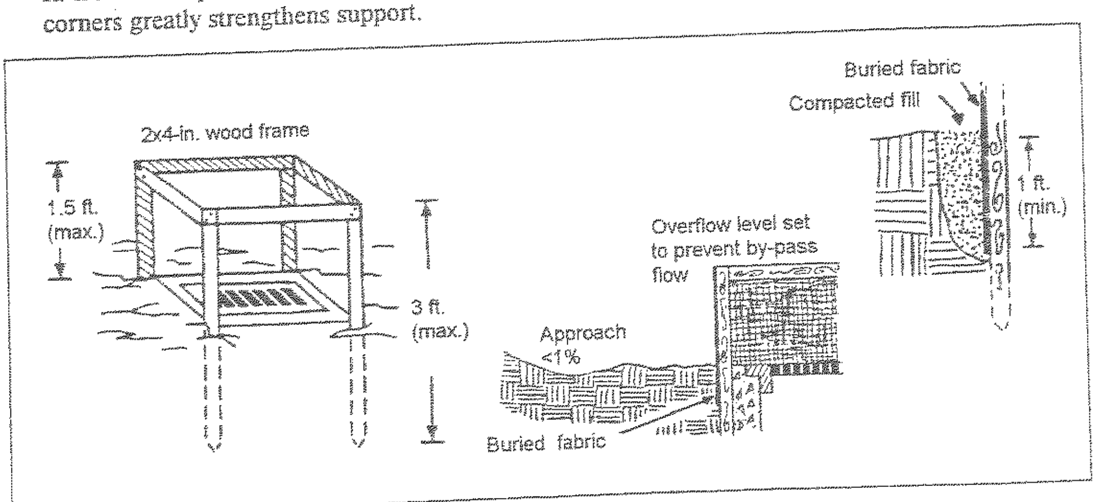


Exhibit 3.52-B. Supporting frame and installation of the fabric.

Installation
(Exhibit 3.52-C)

1. To prevent runoff from bypassing the inlet, set the top of the fabric at least 6 in. below the downslope ground elevation, OR build a temporary dike (compacted to 6 in. higher than the fabric) on the low side of the inlet (see *Exhibit 3.52-C*).
2. Cut the fabric from a single roll to eliminate joints. (Provide at least 2 ft. of overlap if a joint is needed.)
3. Bury the bottom of the fabric at least 1 ft. deep, backfill, and compact the backfill (see *Exhibit 3.52-B*).
4. Space the support posts evenly against the inlet perimeter a maximum of 3 ft. apart, and drive them about 1½ ft. into the ground. (Overflow must fall directly into the inlet and not on unprotected soil.)

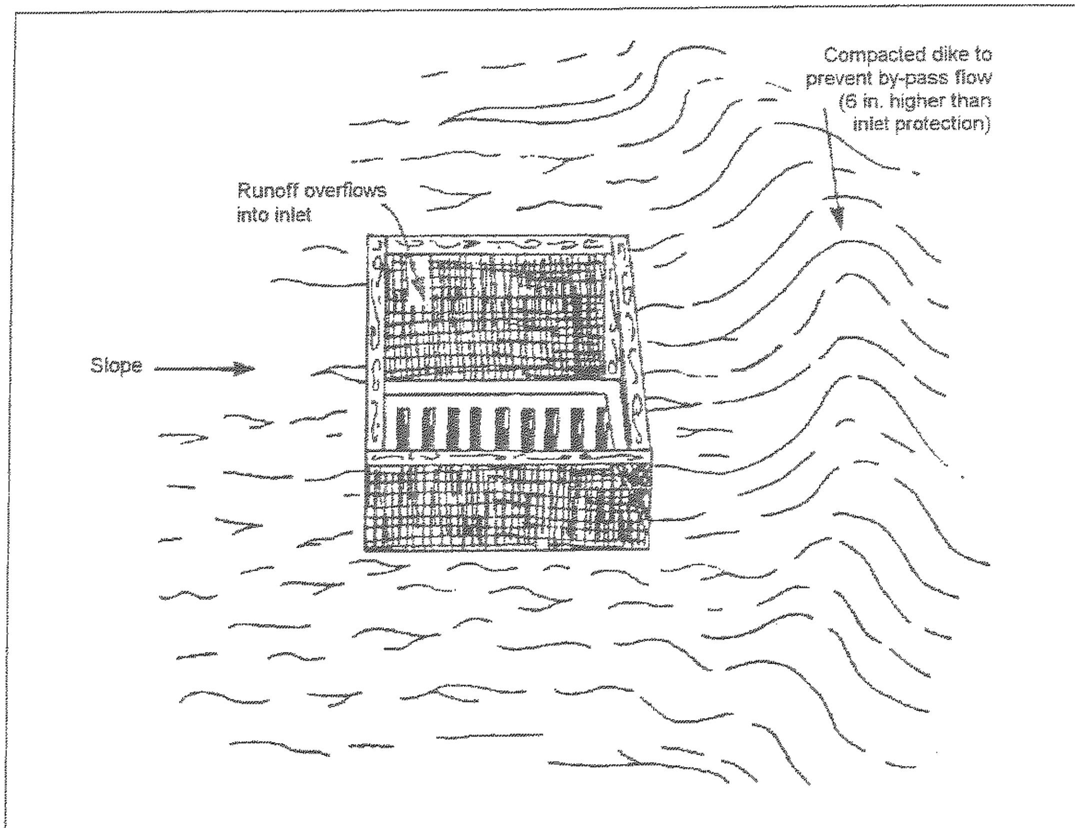


Exhibit 3.52-C. Prevent bypass flow with a temporary dike downslope of the inlet.

Maintenance

* Inspect the fabric barrier after storm events, and make needed repairs immediately.
* Remove sediment from the pool area to provide storage for the next storm. Avoid damaging or undercutting the fabric during sediment removal.
* When the contributing drainage area has been stabilized, remove and properly dispose of all construction material and sediment, grade the area to the elevation of the top of the inlet, then stabilize.

Common concerns

Posts and fabric not supported at the top—results in collapse of the structure.
Fabric not properly buried at bottom—results in undercutting.
Top of fabric barrier set too high—results in the flow bypassing the storm inlet or collapsing the structure.
Temporary dike below drop inlet not maintained—results in the flow bypassing the storm inlet.
Sediment not removed from pool—results in inadequate storage volume for the next storm.
Fence not erected against drop inlet—results in erosion and undercutting.
Land slope at storm drain too steep—results in high flow velocity, poor trapping efficiency, and inadequate storage volume; excavation of the sediment storage area may be necessary.

Practice 3.53
Block and Gravel Drop Inlet Protection

Purpose
(Exhibit 3.53-A)

* To trap sediment at the approach to a storm drain inlet, allowing full use of the storm drain system during the construction period.

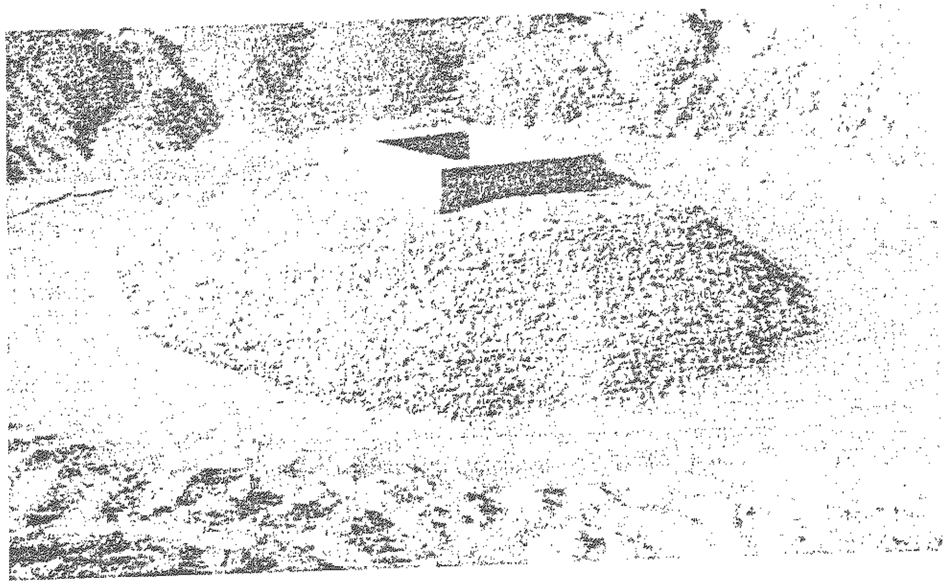


Exhibit 3.53-A. A block and gravel inlet protection forms a low dam, creating a temporary settling pool.

Requirements
(Exhibits 3.53-B and C)

Contributing drainage area: 1 acre maximum.
Capacity: Runoff from a 2-yr. frequency, 24-hr. duration storm event entering the storm drain without bypass flow.
Height of barrier: 1-2 ft., measured from the bottom of the sediment pool.
Sediment pool dewatering: One or more blocks in the bottom row placed with openings horizontal and covered with wire screen (hardware cloth) and gravel.
Gravel: 1 in. diameter or smaller (INDOT CA No. 5) on the outside face of the blocks to control drainage rate.
Side slopes: 2:1 or flatter, with top of the gravel 2-4 in. lower than top of the block structure.
Approach: Pool area flat (less than 1% slope), with sediment storage 945 cu.ft./acre disturbed.

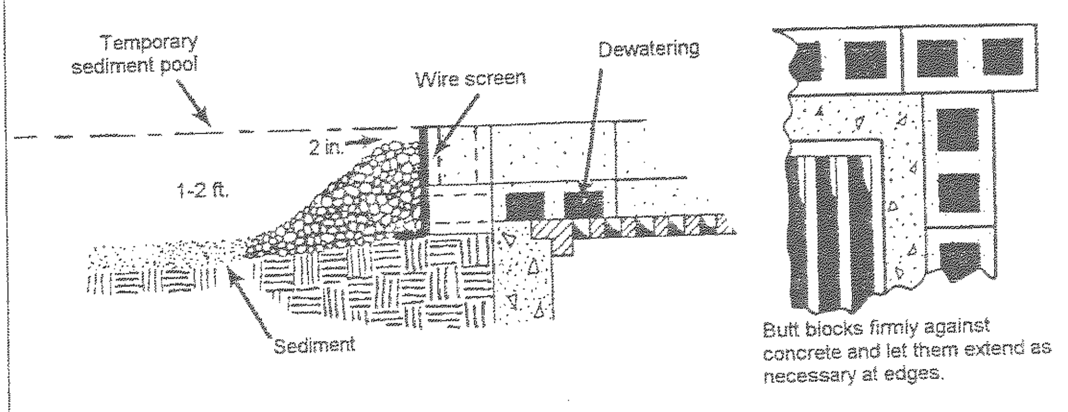


Exhibit 3.53-B. Cross-sectional view of a block and gravel inlet protection.

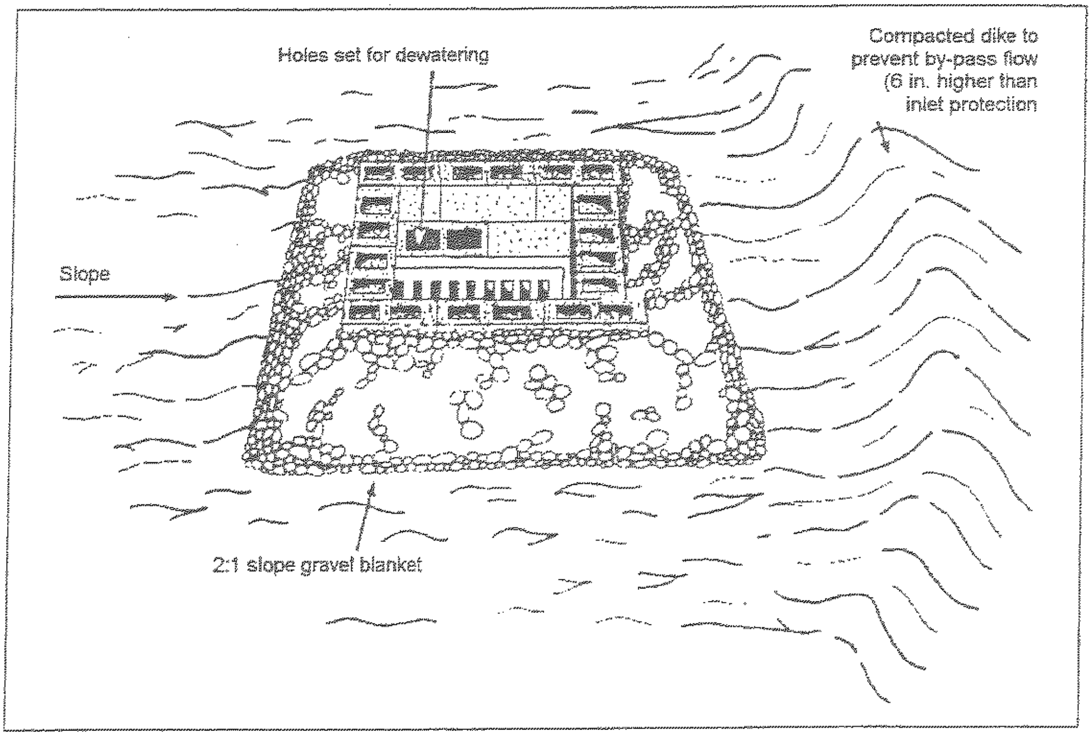


Exhibit 3.53-C. Perspective view of a block and gravel inlet protection.

Installation

1. To reduce by-pass flow, ensure that the top of the blocks are at least 6 in. below ground elevation on the downslope side of the inlet. This may require constructing below the inlet a temporary dike (compacted to at least 6 in. higher than the blocks and stabilized appropriately) OR using the block and gravel inlet protection in conjunction with an excavated drop inlet protection (Practice 3.51).
2. Excavate the foundation for the blocks on level grade at least 2 in. below the top of the storm drain.
3. Place the bottom row of blocks at the edge of the storm drain, butting them firmly against the concrete and letting them extend beyond the corners (see *Exhibit 3.53-B*).
4. If necessary, support the blocks laterally with 2 x 4-in. wood studs (not mortar) through the block openings.
5. On each side of the bottom row, turn one block so its openings face horizontally to allow for sediment pool drainage, and place wire screen (hardware cloth) over the openings to hold the gravel in place (see *Exhibit 3.53-B*).
6. Place gravel around blocks on a 2:1 or flatter slope, leaving 2-4 in. between the top of the gravel and the top of the blocks.

Maintenance

* Inspect the inlet protection after each storm event, removing sediment and making needed repairs immediately.
* When the contributing drainage area has been stabilized, remove and properly dispose of all construction material and sediment, then stabilize.

Common concerns

Top of structure too high—results in water bypassing the structure causing severe erosion.
Blocks not placed firmly against storm drain inlet—results in scour holes developing.
Drainage area too large—results in poor trap efficiency and/or sediment overload.
Approach to drain too steep—results in high flow velocity and poor trap efficiency; solve by installing an excavated basin in the approach (Practice 3.51).
Sediment not removed following a storm—results in sediment entering the storm drain.

Practice 3.54
Straw Bale Drop Inlet Protection

Purpose
(Exhibit 3.54-A)

* To capture sediment at the inlet to a storm drain, allowing full use of the drain system during the construction period.

NOTE: This practice not recommended for paved surfaces due to lack of an anchoring system.

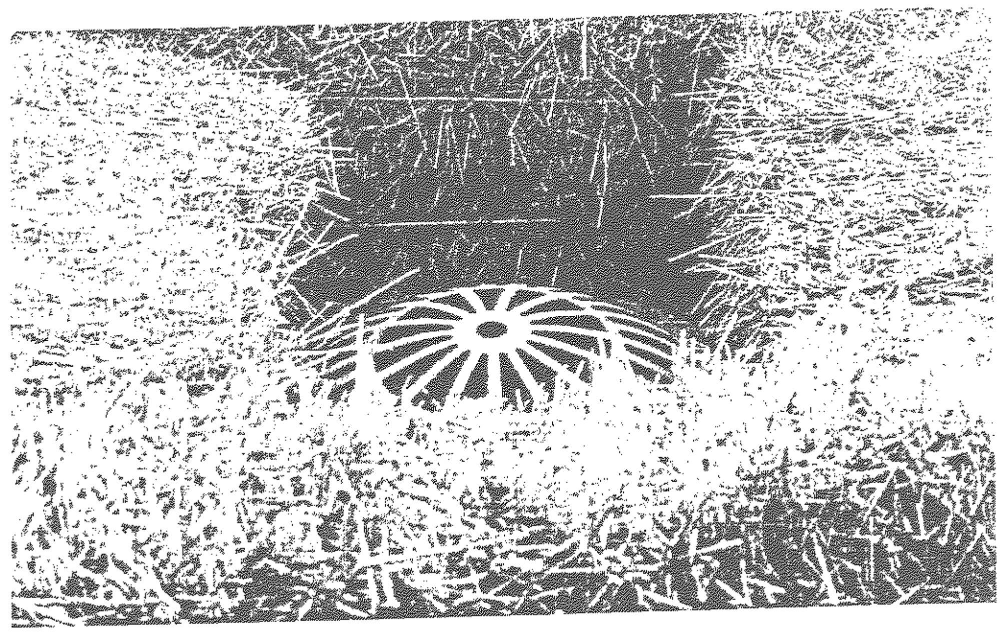


Figure 3.54-A. Straw bale drop inlet protection.

Requirements

Contributing drainage area: 1 acre maximum.
Effective life: Less than 3 months.
Capacity: Runoff from a 2-yr. frequency, 24-hr. duration storm event entering a storm drain without by-pass flow.
Approach: Pool area flat (less than 1% slope), with sediment storage of 945 cu.ft./acre disturbed.
Bale dimensions: Approximately 14 in. x 18 in. x 36 in.
Height of bales above inlet: 14 in. (i.e., 18-in. high bales entrenched 4 in.).
Anchoring: Two 36-in. long (minimum) steel rebars or 2 x 2-in. hardwood stakes driven through each bale.

Installation
(Exhibits 3.54-B and C)

1. To reduce by-pass flow, ensure that the top of the bales will be at least 6 in. below ground elevation on the downslope side of the inlet. This may require constructing below the inlet a temporary dike (compacted to 6 in. higher than the top of the bales) OR using the straw bale drop inlet protection in conjunction with an excavated drop inlet protection (Practice 3.51).
2. Excavate a trench at least 4 in. deep and a bale's width around the inlet.
3. Place the bales lengthwise in the trench so the bindings are oriented around the sides, rather than top and bottom, to minimize deterioration of the bindings.
4. Allow the bales to overlap at the corners, and abut them tightly against each other.
5. Anchor the bales by driving two 36-in. long steel rebars or 2x2-in. hardwood stakes through each bale until nearly flush with the top. Drive the first stake at an angle towards the previously laid bale to force the bales together.
6. Chink (i.e., tightly wedge) straw into any gaps between bales to prevent sediment-laden water from flowing directly into the inlet.
7. Backfill and compact the excavated soil 4 in. high against the outside of the bales.

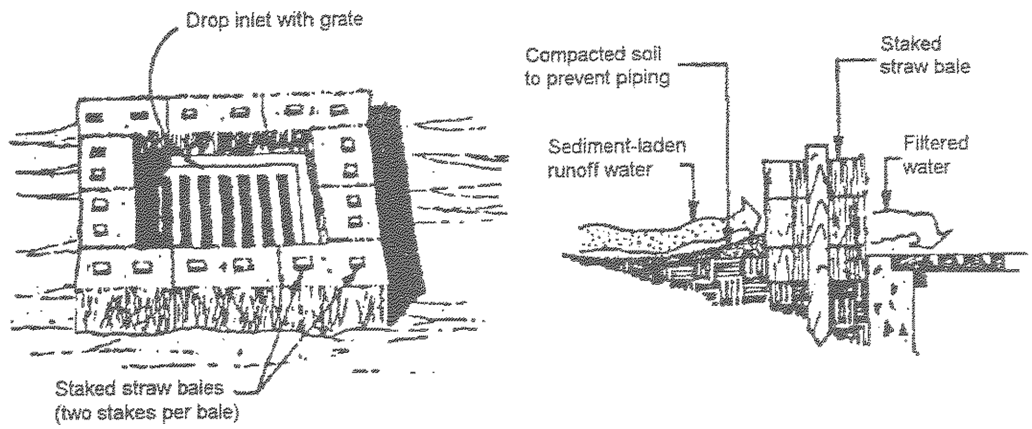


Exhibit 3.54-B. Oblique view of a properly installed straw bale drop inlet protection.

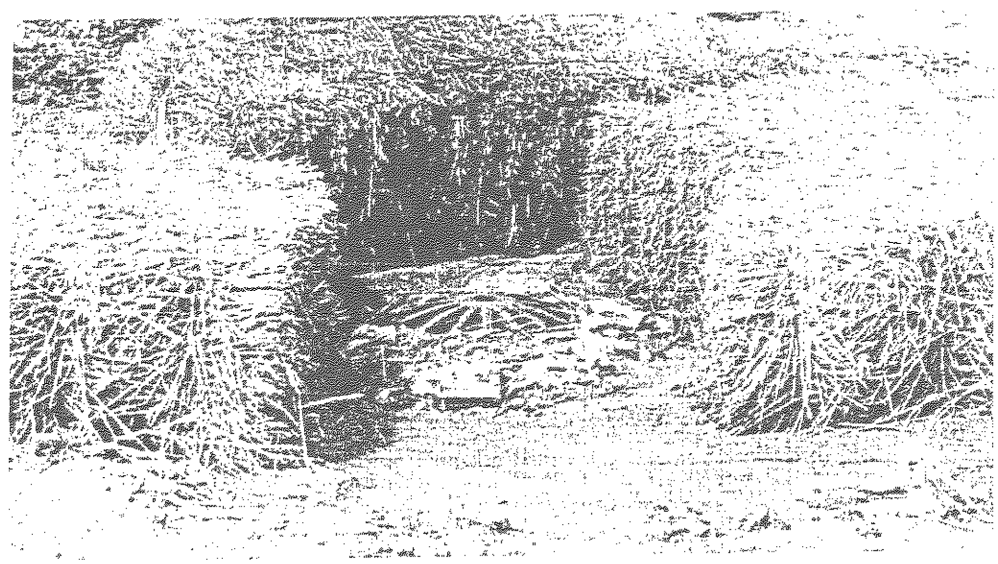


Exhibit 3.54-C. Here's an almost totally ineffective straw bale drop inlet protection--bales oriented wrong (i.e., bindings exposed to the ground), and not overlapped, abutted, staked, or chinked.

Maintenance

* Inspect the drop inlet protection after each storm event, and make needed repairs immediately.
* Remove sediment from the pool area to ensure adequate runoff storage for the next rain, taking care to not damage or undercut the bales.
* When the contributing drainage area has been stabilized, remove all bales, construction material, and sediment and dispose of properly, grade the disturbed area to the elevation of the top of the inlet and stabilize.

Common concerns

Flow undercutting the bales—because the bales were not entrenched and backfilled.

Bales dislodged—because the bales were not securely anchored.

Flow by-passing the inlet—because the dike was not maintained or was too low.

Sediment not removed from pool—results in inadequate storage volume for the next storm event.

Land slope at inlet too steep—results in high flow velocity, poor trapping efficiency, inadequate storage volume; to correct, excavate the sediment storage area.

Bales falling apart—because they were laid with bindings running top and bottom rather than around sides or were utilized beyond their 3-mo. effective life.

Practice 3.55
Slotted-Barrel Drop Inlet Protection

Purpose
(Exhibit 3.55-A)

* To trap sediment at the entrance to a round casting-covered drop inlet storm drain, allowing full use of the drain system during the construction period.

NOTE: This practice not recommended for paved surfaces due to lack of an anchoring system.

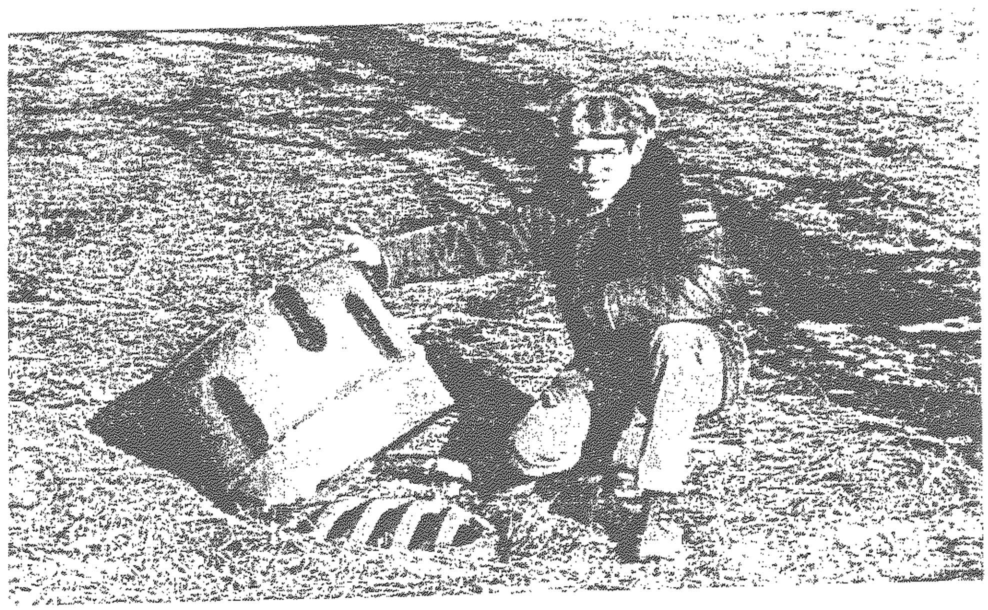


Exhibit 3.55-A. A slotted-barrel protects this drop inlet from sediment inflow.

Requirements

Contributing drainage area: 1 acre maximum.
Capacity: Runoff from a 2-yr. frequency, 24-hr. duration storm event entering the storm drain without bypass flow.
Height of riser: 1 ft. minimum.
Approach: Pool area flat (less than 1% slope), with sediment storage of 945 cu.ft./acre disturbed.
Barrel dimension: Equal to or greater than the casting grate.
Geotextile fabric (optional): For filtration, wrapped around the outside of the barrel riser.
Gravel (optional): For filtration, INDOT CA No. 1 mounded around base of riser.

Installation
(Exhibits 3.55-B)

1. Set barrel riser height at least 6 in. below ground elevation on the downslope side of the inlet to prevent runoff from by-passing the inlet.
2. If necessary, on the low side of the inlet, build a temporary dike compacted to 6 in. higher than the riser and stabilized appropriately.
3. Cut slots at least 1 in. wide and 5 in. long in the barrel, and cut out the barrel ends (see *Exhibit 3.55-B*).
4. Place the barrel riser over the casting grate.
5. If using geotextile fabric, wrap it around the riser before placement and tuck it under the bottom of the barrel; attach the fabric top to the barrel with cord or wire.
6. If using gravel, mound it around the base of the barrel no higher than the bottom of the lowest slots.
7. Consider using an excavated drop inlet protection in conjunction with this practice to improve trap efficiency, and provide sediment storage capacity (Practice 3.51).

Maintenance

* Inspect the structure after each storm event.
* Remove accumulated sediment and make needed repairs immediately.
* When the contributing drainage area has been stabilized, remove and properly dispose of all construction material and sediment and stabilize.

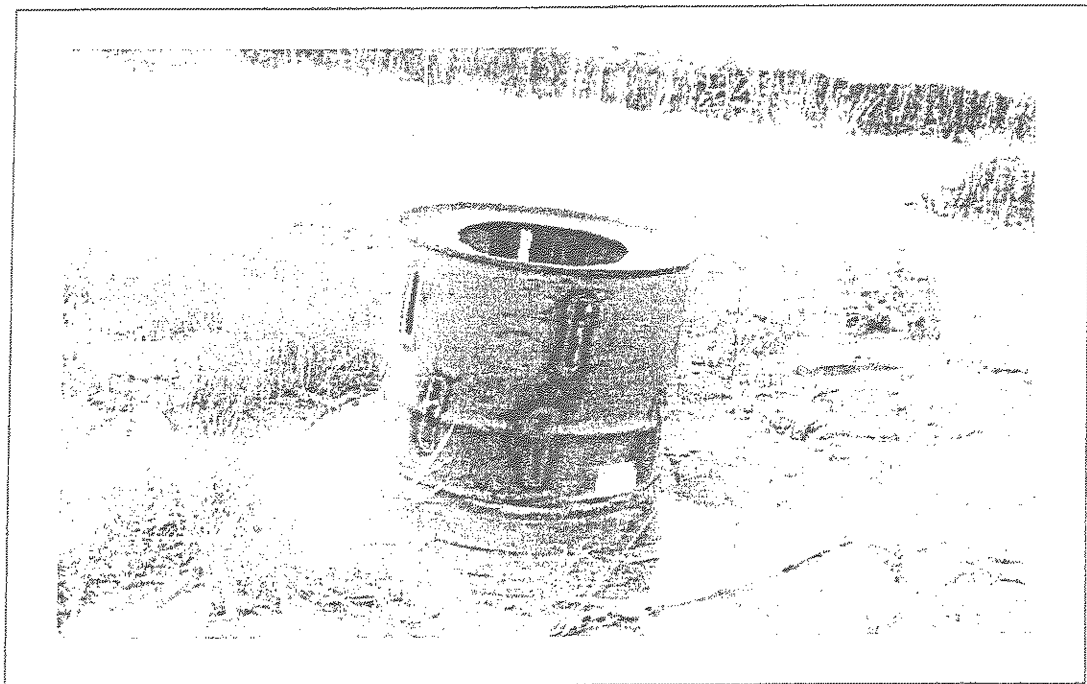


Exhibit 3.55-B. A slotted barrel in place with a hole in the top to allow high storm flow to enter.

Common concerns

Top of riser too high—results in by-pass storm flow, which causes severe erosion or excessive ponding.

Barrel end not removed—results in obstruction of high storm flow causing by-pass flow, or the barrel floats off the casting allowing excessive sediment to enter the storm drain.

Slots of riser too small—slots clog with debris blocking flow.

Drainage area too large—results in poor trap efficiency and/or sediment overload.

Approach to drain too steep—causes high flow velocity and poor trap efficiency; correct by installing an excavated drop inlet protection in the approach (Practice 3.51).

Sediment not removed following a storm—results in sediment entering the storm drain.

Casting diameter too large or barrel does not fit over adequately—results in excessive sediment entering the storm drain.

Inadequate trap efficiency—correct by mounding gravel greater than 1 in. in diameter around the riser up to the bottom of the lower slots.

Practice 3.56
Gravel Donut Inlet Protection

Purpose
(Exhibit 3.56-A)

* To trap sediment at the approach to a storm drain inlet, allowing full use of the drain system during the construction period.

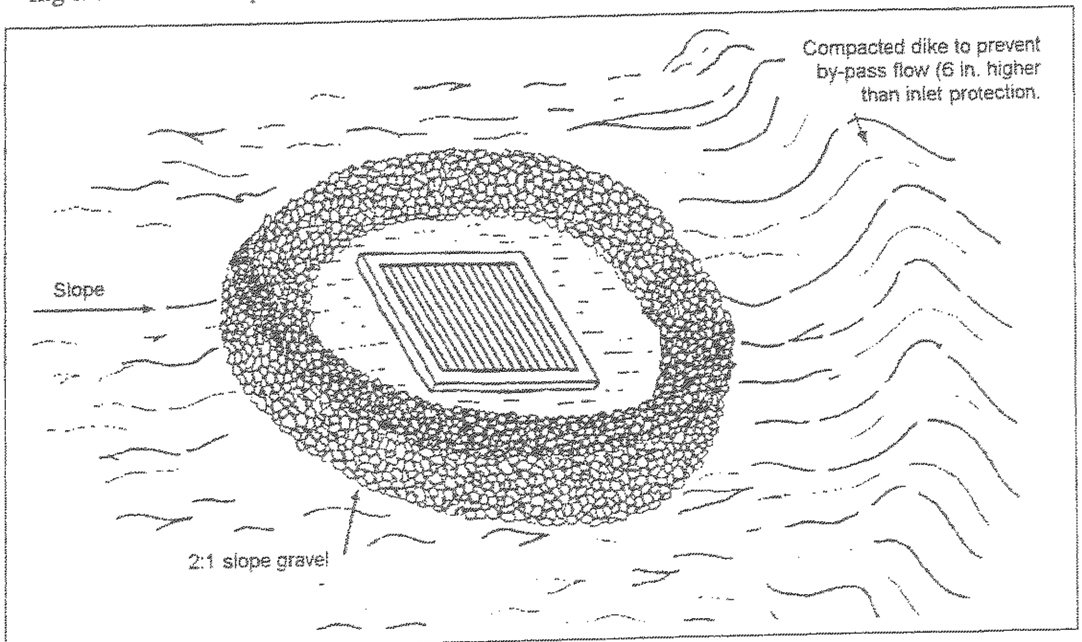


Exhibit 3.56-A. Perspective view of a gravel donut inlet protection with a temporary dike down slope.

Requirements
(Exhibit 3.56-B)

Contributing drainage area: 1 acre maximum.
Capacity: Runoff from a 2-yr. frequency, 24-hr. duration storm event entering a storm drain without bypass flow.
Height of structure: 1-2 ft. above top of inlet.
Gravel for donut: INDOT CA No. 1 (outside face, INDOT CA No. 5).
Slope of donut: Outside, 2:1 or flatter; inside 3:1 or flatter.

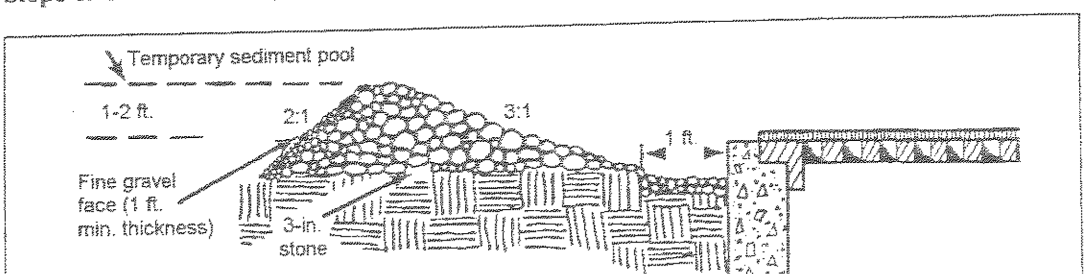


Exhibit 3.56-B. Cross-section view of a gravel donut drop inlet protection.

Installation

1. Excavate an 8 in. deep and minimum 1 ft. wide area immediately out from the storm drain.
2. Around that excavated area, lay a ring of gravel (INDOT CA No. 1) to a height 1-2 ft. above the top of the inlet and having a 2:1 or flatter outside slope and a 3:1 or flatter inside slope (but be sure the toe of the inside slope does not extend into the excavated area.) The top of the gravel ring on the downslope side of the inlet should be 6 in. below ground elevation to reduce bypass flow.
3. Cover the outside face of the donut with at least 1 ft. of INDOT CA No. 5 gravel, maintaining a 2:1 or flatter slope.

4. Also blanket the area from the toe of the inside slope to the inlet structure with INDOT CA No. 5, leaving the excavated area adjacent to the structure recessed at least 4-in. to keep stone out of the storm drain.
5. Where necessary to prevent bypass flow, construct a temporary dike on the downslope side of the inlet, compacting it to at least 6 in. higher than the top of the gravel donut, and stabilize (see *Exhibit 3.56-A*)..

Maintenance

* Inspect the structure after each storm event, removing sediment and making needed repairs immediately.
* When the contributing drainage area has been stabilized, remove and properly dispose of any unstable sediment and construction material, and re-stabilize.

Common concerns

Top of structure too high—results in runoff bypassing the structure causing severe erosion.

Drainage area too large—results in poor trap efficiency and/or sediment overload.

Approach to drain too steep—results in high flow velocity and poor trap efficiency; solved by installing an excavated drop inlet protection in the approach (Practice 3.51).

Sediment not removed following a storm event—results in sediment entering the storm drain.

Stone in gravel donut not large enough or inside slope too steep—results in poor sediment filtration efficiency.

Stone enters the storm drain—caused by insufficient recessed area or distance between the toe of the inside slope and the inlet.

Sub-Section 3.6

TEMPORARY CURB INLET PROTECTIONS

Practice 3.61
Gravel Curb Inlet Protection

Purpose
(Exhibit 3.61-A)

* To prevent excessive sediment from entering storm sewers at curb inlets, allowing full use of the storm drainage system during the construction period. This practice is especially important when storm sewers empty off-site outside the construction area.

NOTES: (1) Trapping sediment at a curb inlet will be difficult if erosion/sediment control measures are not installed to reduce the volume of sediment reaching the inlet. (2) If ponding at an inlet would be a problem, consider block and gravel curb inlet protection (Practice 3.62.)

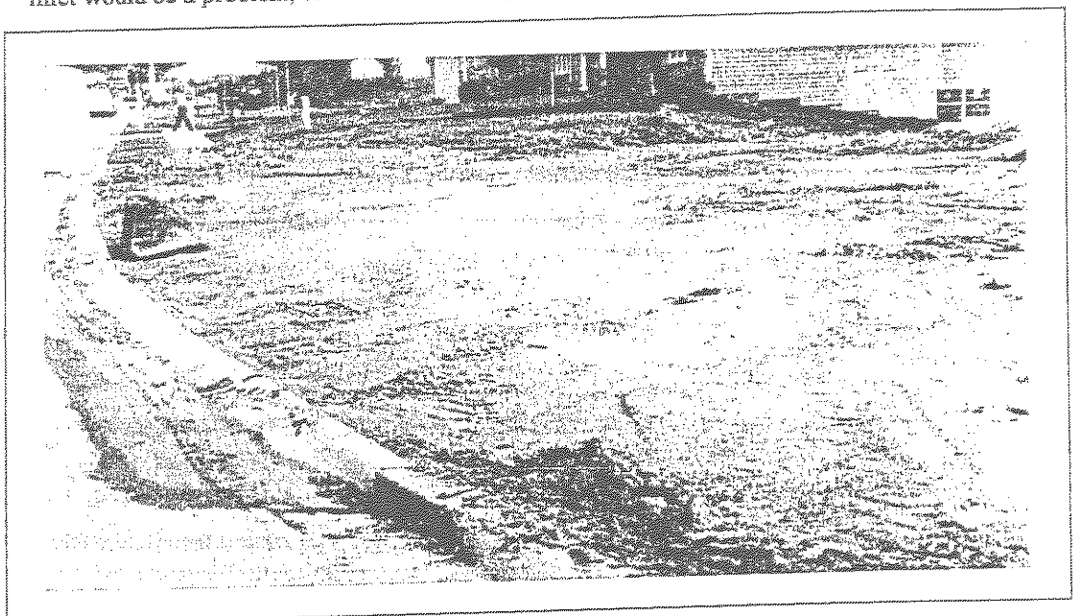


Exhibit 3.61-A. This would have been good spot for a gravel curb inlet protection.

Requirements
(Exhibit 3.61-B)

Contributing drainage area: 1 acre maximum.

Capacity: Runoff from a 2-yr. frequency, 24-hr. duration storm event entering the storm drain without bypass flow.

Location: At curb inlets where ponding is not likely to cause inconvenience or damage.

Gravel: 1-2 in. diameter (INDOT CA No. 2)

Wire mesh: Chicken wire or hardware cloth with 1/2-in. openings.

Geotextile fabric (optional): For filtration.

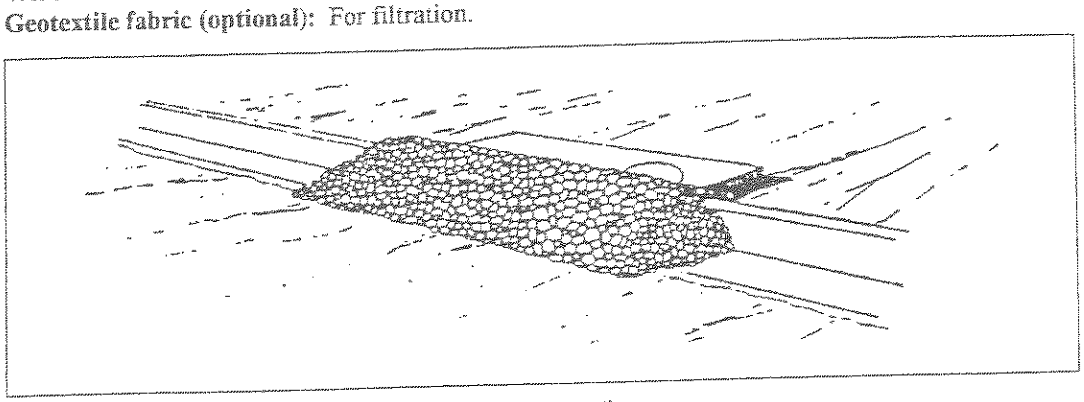


Exhibit 3.61-B. Perspective view of a gravel curb inlet protection.

Installation
(Exhibit 3.61-B)

1. Install gravel curb inlet protections as soon as the streets are paved in a new development situation or before land-disturbing activities in stabilized areas.

2. Place wire mesh over the curb inlet opening and/or grate so it extends at least 12 in. beyond both top and bottom of the opening/grate.
3. Install geotextile fabric over the wire mesh for additional filtration (optional).
4. Pile gravel over the wire mesh to anchor it against the curb, covering the inlet opening completely.

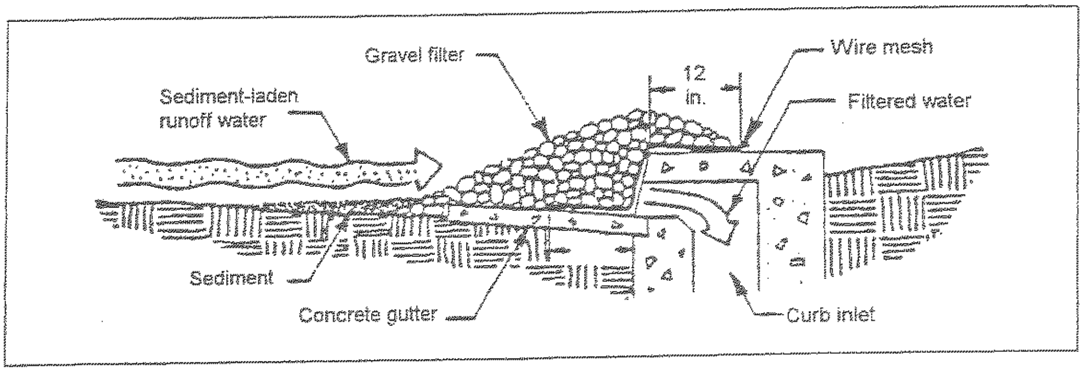


Exhibit 3.61-C. Cross-section detail of a gravel curb inlet protection.

Maintenance

* After each storm event, remove sediment and replace the gravel; replace the geotextile filter fabric if used.
* Periodically remove sediment and tracked-on soil from the street (but not by flushing with water) to reduce the sediment load on the curb inlet practice.
* Inspect periodically, and repair damage caused by vehicles.
* When the contributing drainage area has been stabilized, remove the gravel, wire mesh, geotextile fabric, and any sediment, and dispose of them properly.

Common concerns

Sediment not removed from roadway and gravel and fabric not replaced following a storm event —results in increased sediment tracking, traffic hazard, and excessive ponding.

Drainage area too large—causes sediment overload at the inlet and/or by-pass flow.

Slope too steep—results in bypass flow and/or dislodgement of the gravel and hardware cloth; consider replacing with or using in combination with a sandbag curb inlet protection (Practice 3.64).

Practice 3.62
Block and Gravel Curb Inlet Protection

Purposes
(Exhibit 3.62-A)

* To prevent excessive sediment from entering storm sewers at curb inlets, allowing full use of the storm drain system during the construction period.
* To minimize ponding at an inlet.

NOTES: (1) Trapping sediment at a curb inlet will be difficult if erosion/sediment control measures are not installed to reduce the volume of sediment reaching the inlet. (2) Use this practice only where traffic would not be adversely affected.

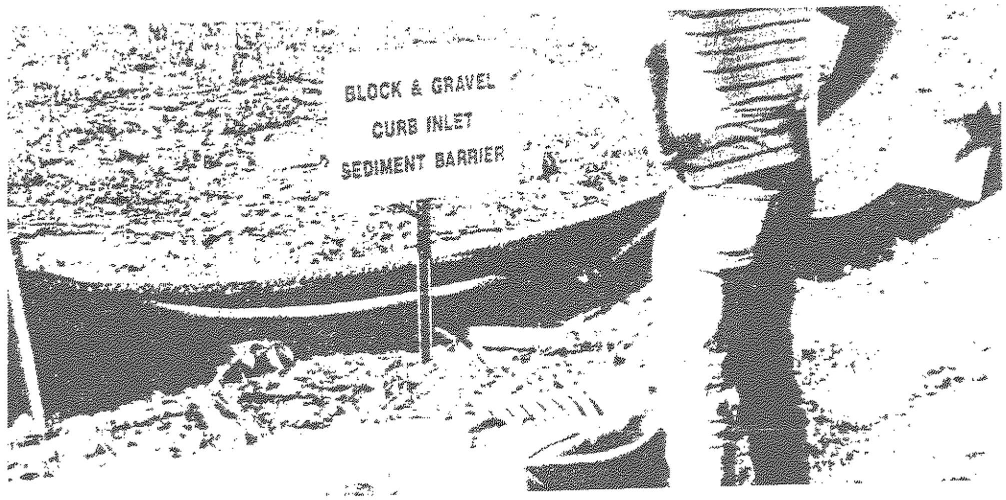


Exhibit 3.62-A. A block and gravel curb inlet protection reduces ponding problems at the inlet.

Requirements
(Exhibits 3.62-B)

Contributing drainage area: 1 acre maximum.
Capacity: Runoff from 2-yr. frequency, 24-hr. duration storm event entering the storm drain without bypass flow.
Location: At curb inlets where ponding is likely to occur without bypass flow.
Gravel: 1-2 in. diameter (INDOT CA No. 2).
Wire mesh: Chicken wire or hardware cloth with 1/2-in. opening.
Geotextile fabric (optional): For filtration.
Traffic barricades: For protection from vehicles.

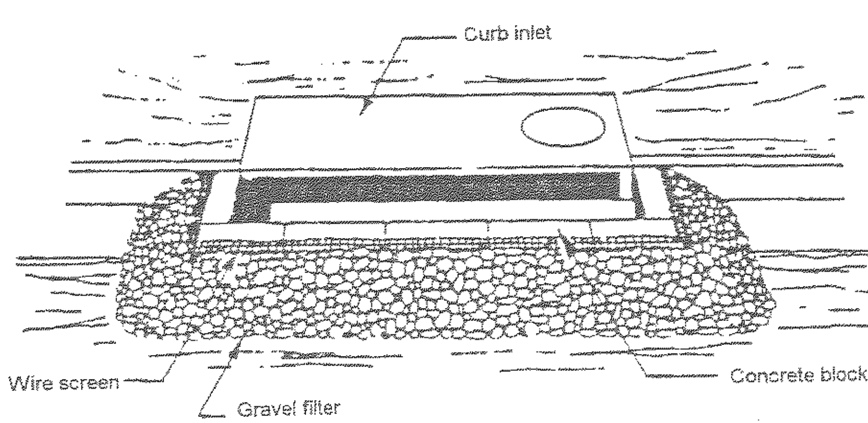


Exhibit 3.62-B. Perspective view of a block and gravel curb inlet protection.

Installation
(Exhibit 3.62-B)

1. Install as soon as streets are paved in a new development or before land-disturbing activities in a stabilized area.
2. At each side of the inlet, place a concrete block lengthwise out from the curb with its openings facing outward (not upward) to serve as a spacer block.
3. Place a row of blocks (openings facing out) across the front of the inlet and abutting the spacer blocks.
4. Cut a 2 x 4-in. wood stud the length of the inlet plus spacer blocks, and insert it through the front-most openings of the spacers to keep the row of blocks ahead of it from being pushed back toward the inlet (see *Exhibit 3.62-C*).
5. Run wire mesh from the top of the blocks, down their outside vertical face, to about 12 in. into the street (see *Exhibit 3.62-C*).
6. Install geotextile fabric over the wire mesh for additional filtration (optional).
7. Pile gravel in front of the barrier up to the top of the blocks. (If the curbs are sloped, use extra wire mesh and gravel to fill in the space between the final block and the curb.)

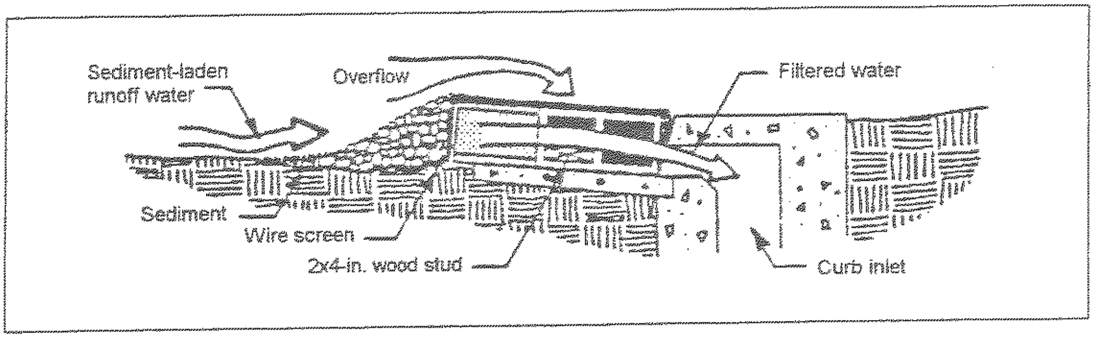


Exhibit 3.62-C. Cross-section detail of block and gravel curb inlet protection.

Maintenance

* After each storm event, remove the sediment and replace the gravel; replace the geotextile fabric, if used.
* Periodically remove sediment and tracked-on soil from the street (but not by flushing with water) to reduce the sediment load on the curb inlet protection.
* Inspect periodically for damage and repair; keep grates free of debris.
* When the contributing drainage area has been stabilized, remove the gravel, wire mesh, geotextile fabric, and any sediment, and dispose of them properly.

Common concerns

Damage by vehicles—results in sediment entering the storm drain or the barrier becoming a traffic hazard.

Sediment not removed, and gravel and fabric not replaced following a storm event—results in increased sediment tracking, traffic hazard, and excessive ponding.

Gravel enters drain—because the wire mesh openings were too big or the mesh did not cover the block openings or gaps.

Drainage area too large—causes sediment overload at the inlet, excessive ponding, or overtopping of the barrier.

Approach to drain too steep—causes high flow velocity, resulting in bypass flow or dislodging of the gravel; consider a sandbag curb inlet protection upslope from the drain (Practice 3.64).

Practice 3.63
Basket Curb Inlet Protection

Purpose
(Exhibit 3.63-A)

* To prevent excessive sediment from entering storm sewers at curb inlets, allowing full use of the storm drain system during the construction period.

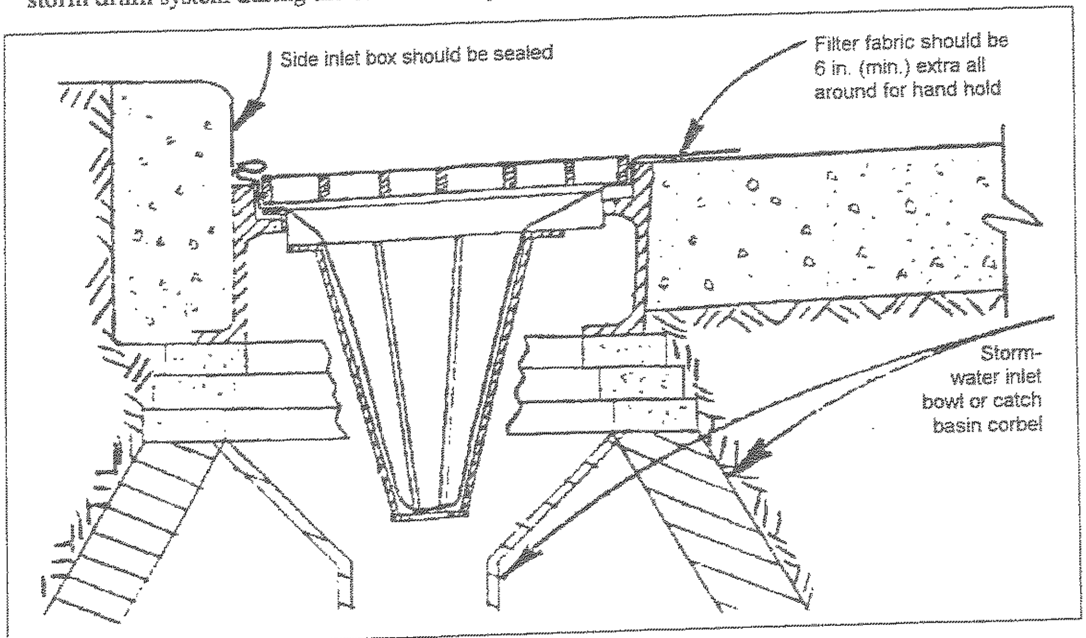


Exhibit 3.63-A. Cross-sectional view of a basket curb inlet protection.

Requirements
(Exhibit 3.63-B)

Location: At curb inlets where barriers surrounding them would be impractical or unsafe.
Contributing drainage area: 1/4 acre maximum.
Capacity: Runoff from a 2-yr. frequency, 24-hr. duration storm event entering the storm drain without bypass flow.
Basket: Fabricated metal with top width-length dimensions such that the basket fits into the inlet without gaps (see *Exhibits 3.63-A and B*).
Geotextile fabric: For filtration.

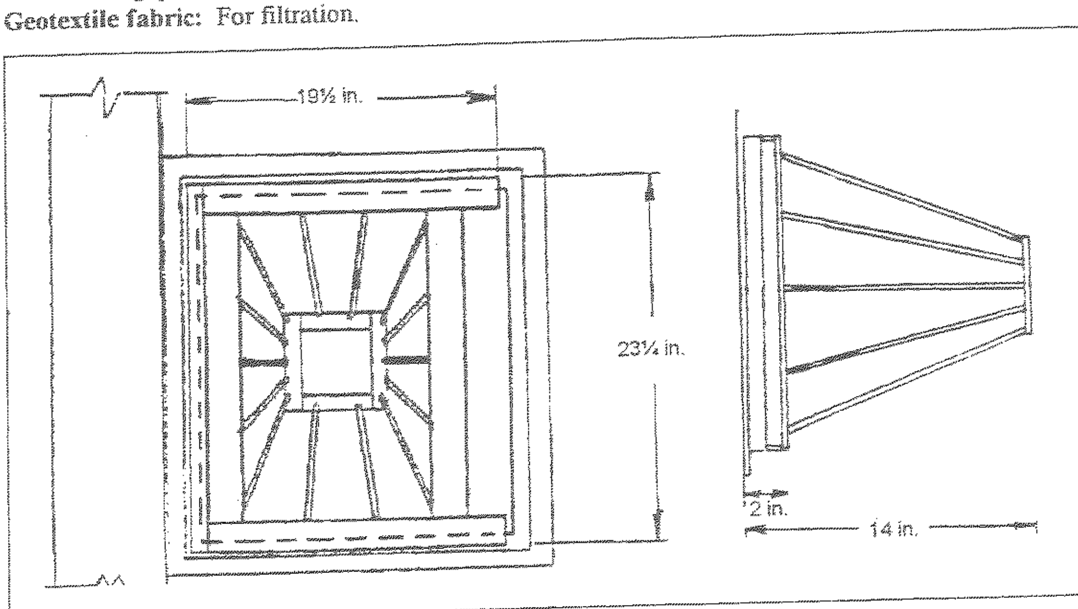


Exhibit 3.63-B. Top view (left) and front view (right) of a basket curb inlet protection.

Installation

1. Install basket curb inlet protections as soon as inlet boxes are installed in a new development or before land-disturbing activities begin in a stabilized area.
2. If necessary, adapt basket dimensions to fit inlet box dimensions, which vary according the manufacturer and/or model.
3. Seal the side inlets on those types of inlet boxes that have them.
4. Remove the grate, and place the basket in the inlet.
5. Cut and install a piece of filter fabric large enough to line the inside of the basket and extend at least 6 in. beyond the frame.
6. Replace the inlet grate, which also serves to anchor the fabric.

Maintenance

* Inspect after each storm event.
* Remove built-up sediment and replace the geotextile fabric after each storm event.
* Periodically remove sediment and tracked-on soil from the street (but not by flushing with wa-ter) to reduce the sediment load on this curb inlet practice.

Common concerns

Sediment not removed and geotextile fabric not replaced following a storm event—results in increased sediment, tracking, traffic hazard, and excessive ponding.

Geotextile fabric permittivity too low—results in rapid clogging, thus severe ponding; sediment enters the drain if the fabric breaks.

Drainage area too large—results in sediment overload and severe ponding; sediment enters the drain if the fabric breaks.

Practice 3.64
Sandbag Curb Inlet Sediment Barrier

Purpose
(Exhibit 3.64-A)

* To trap sediment on paved streets that receive relatively small runoff flows, preventing it from being transported further down the street or into an inlet.

NOTES: (1) Trapping sediment at a curb inlet will be difficult if erosion/sediment control measures are not installed to reduce the volume of sediment reaching the inlet. (2) This practice can be used in conjunction with other curb inlet sediment controls.

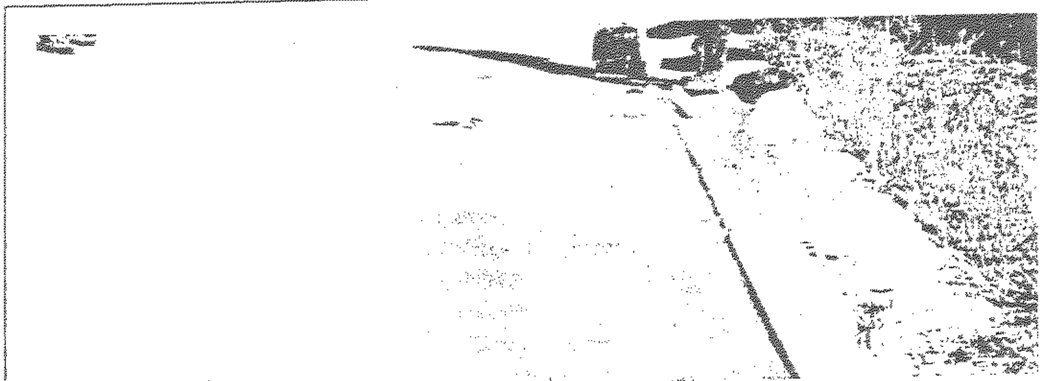


Exhibit 3.64-A. A sandbag curb inlet sediment barrier.

Requirements
(Exhibit 3.64-B)

Location: On curbed paved street down grade from light construction activity (e.g., individual home) and above the inlet.

Contributing drainage area: 1 acre maximum.

Capacity: Runoff from a 2-yr. frequency, 24-hr. duration storm event entering the storm drain without bypass flow.

Height: 1-3 layers of sandbags (as necessary)

Length: As needed to intercept runoff (3 ft. minimum).

Traffic barricades (optional): As needed to prevent vehicles from hitting the barrier.

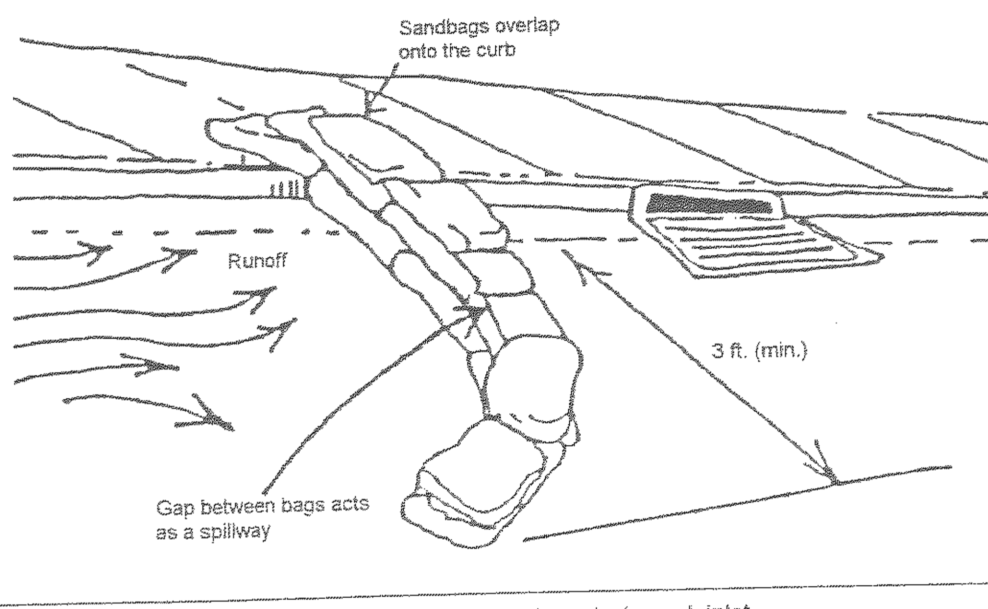


Exhibit 3.64-B. Detail of a sandbag curb sediment barrier to protect a curb inlet.

Installation

1. Fill bags approximately half full with sand or fine gravel.
2. Upslope from the curb inlet, lay the bags tightly end to end in a row curving from the curb and away from the inlet.
3. Overlap the barrier onto the curb, and extend it a minimum of 3 ft. into the street to intercept the runoff.
4. If using more than one row, overlap the bags with the row beneath, and leave a one-bag gap in the middle of the top row to serve as a spillway.
5. For additional storage capacity, construct a series of sandbag barriers along the curb so each one traps small amounts of sediment.

Maintenance

* Inspect frequently for damage by vehicular traffic, and repair if needed.
* Inspect after each storm event.
* Remove sediment (but not by flushing) when it reaches half the height of the barrier.
* Deposit removed sediment where it will not enter storm drains.

Common concerns

Vehicular hazard if barrier is too high or too long--consider using traffic barricades.

Vehicular damage to barrier—repair immediately.

Sandbags not placed tightly together—results in poor trap efficiency.

Drainage area too large—results in poor trap efficiency and/or sediment overload.

Approach too steep—causes high flow velocity resulting in poor trap efficiency and sandbags dislodging; use a different inlet protection practice.

Sediment not removed following a storm event—results in increased sediment tracking, traffic hazard, and excessive ponding.

Sub-Section 3.7

SEDIMENT TRAPS AND BARRIERS

Practice 3.71
Temporary Sediment Trap

Purpose
(Exhibit 3.71-A)

* To prevent offsite sedimentation by trapping sediment at designated locations accessible for clean-out.

Exhibit 3.71-A. A temporary sediment trap with rock spillway.

Requirements
(Exhibits 3.71-B, C, and D)

Drainage area: 5 acres maximum.
Structure life: Limited to 2 yrs.
Sediment storage: 1,800 cu.ft./acre disturbed minimum.
Embankment: Machine-compacted earth fill having 5 ft. maximum height, 2:1 or flatter side slopes, and 5 ft. minimum top width.
Spillway outlet capacity: Routed 2-yr. frequency, 24-hr. duration storm event.
Spillway outlet freeboard: 6 in. minimum.
Stone: INDOT Revetment Riprap; inside facing lined with 1 ft. of INDOT CA No. 5.
Side slopes: Spillway and excavated basin 2:1 or flatter.
Protection from piping: Geotextile fabric for separation and filtration, bedding, or cut-off trench between stone spillway outlet section and compacted embankment.
Spillway depth: 1½ ft. minimum below settled top of the embankment.
Spillway bottom width: Based on drainage area as shown in *Exhibit 3.71-D.*
Outlet apron: 5 ft. long (minimum) on level grade with filter fabric foundation to ensure exit velocity to receiving stream is non-erosive.
Outlet option: A pipe with slotted outlet riser as the trap outlet; should be consistent with SCS standards and specifications for ponds (see Appendix B).

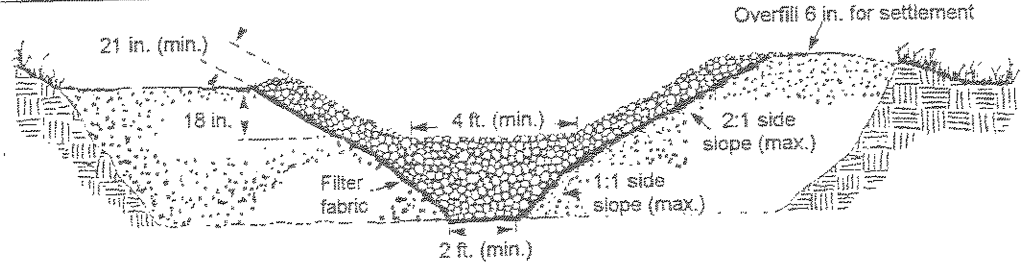


Exhibit 3.71-B. Earth embankment and stone outlet section of a temporary sediment trap.

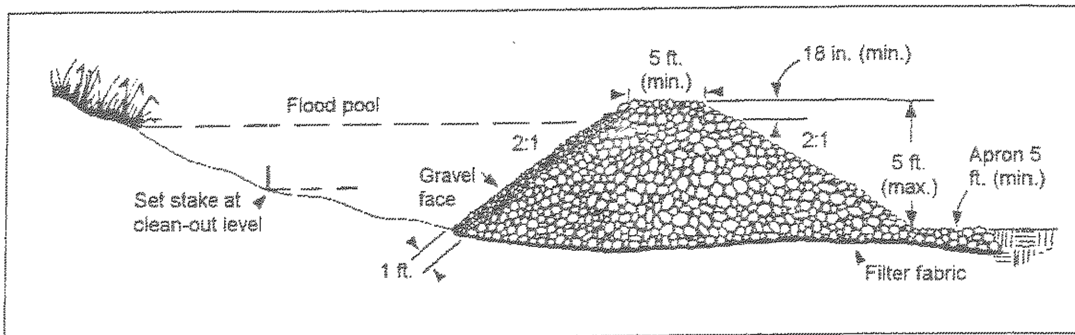


Exhibit 3.71-C. Cross-sectional view of the stone outlet section.

Exhibit 3.71-D. Minimum spillway design for a temporary sediment trap.

Drainage area	Minimum bottom width
1 acre	4 ft.
2 acres	6 ft.
3 acres	8 ft.
4 acres	10 ft.
5 acres	12 ft.

Installation

EMBANKMENT:

1. Locate the trap as near the sediment source as topography allows.
2. Divert runoff from all undisturbed areas away from the trap site.
3. Clear, grub, and strip all vegetation and root mat from the embankment area.
4. Using stable mineral soil free of roots, rocks, brush and debris, place fill in 9-in. lifts (max).
5. Compact each lift so the side slopes are 2:1 or flatter (3:1 recommended for backslope to improve stability of stone spillway).
6. Overfill the embankment to 6 in. above the design elevation to allow for settling.

OUTLET SECTION:

1. Excavate a trapezoidal stone outlet section from the compacted embankment (*Exhibit 3.71-B*).
2. Install geotextile fabric, extending it up the sides to the top of the embankment.
3. Place specified stone to the lines and grades, working smaller stones into voids to achieve a dense mass. The spillway crest should be level with the width specified (minimum 4 ft.); spillway depth should be 1½ ft. minimum, measured from the highest stones in the spillway to the top of the dam.
4. Keep the base of the stone outlet section at least 2 ft. thick through the level section and the downstream face of the dam.
5. Extend the outlet apron below the toe of the dam on level grade until stable conditions are reached (5 ft. minimum).
6. Make the edges and end of the stone apron section flush with the surrounding ground. (No overfall should exist.)
7. Cover the inside face of the stone outlet section with a 1-ft. layer of INDOT CA No. 5.
8. Stabilize the embankment.
9. Set a stake at one-half the design depth to mark the cleanout level.

Maintenance

* Inspect temporary sediment traps after each storm event, and immediately repair any erosion and piping holes.
* Remove sediment when it has accumulated to one-half the design depth.
* Replace spillway gravel facing if clogged.
* Inspect vegetation, and re-seed if necessary.
* Check the spillway depth periodically to ensure a minimum of 1½-ft. depth from the lowest point of the settled embankment to highest point of the spillway crest, and fill any low areas to maintain design elevation.

Practice 3.72
Temporary Sediment Basin

Purpose
(Exhibit 3.72-A)

* To prevent offsite sedimentation by retaining sediment on the construction site.

NOTE: This practice may be used where failure of the embankment would not endanger life; damage homes, commercial or industrial buildings, main highways, or railroads; or disrupt public utility services.

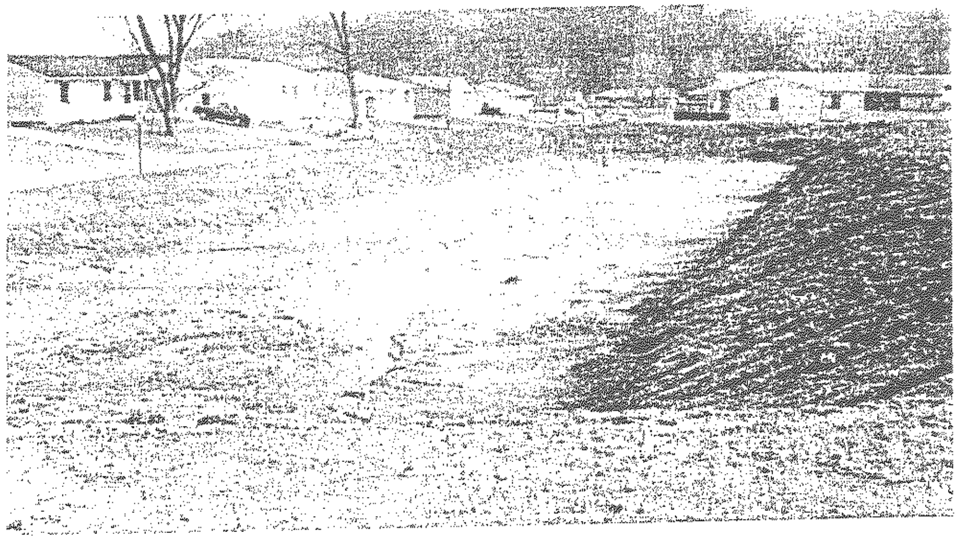


Exhibit 3.72-A. This temporary sediment basin will be used as a dry detention pond after construction in the area is completed and the site stabilized.

Requirements
(Exhibits 3.72-B and C)

GENERAL:

Dam height: 10 ft. or less.

Contributing drainage area: 30 acres maximum.

Structure life: Limited to 3 yrs.

Sediment storage: 1,800 cu.ft./acre disturbed, minimum.

Trap efficiency: 2:1 or greater length-to-width ratio.

PRINCIPAL SPILLWAY:

Riser and barrel: Vertical pipe riser and horizontal pipe barrel able to withstand maximum external loading without yielding, buckling, or cracking. (Should be consistent with SCS standards and specifications for ponds [see Appendix B].)

Capacity: Runoff from a 10-yr. frequency, 24-hr. duration storm event without discharging through the emergency spillway.

Anti-seep collars: At least one watertight collar (1½ ft. minimum projection) around a barrel 8 in. or larger in diameter.

Anti-floatation block: Riser held in place with an anchor having a buoyant weight greater than 1.1 times that of water displaced by the riser and any exposed portion of the barrel.

Trash guard (optional): At the top of the riser.

Outlet: Stable for design pipe discharge. (Riprap outlet apron needed unless the foundation is rock.)

EMBANKMENT:

Top width: 6 ft. minimum.

Side slopes: 2.5:1 or flatter.

Settlement allowance: 10% of the design height.

Fill material: Stable mineral soil compacted in 6-8 in. lifts while moist.

EMERGENCY SPILLWAY:

Capacity: Routed peak flow from a 25-yr. frequency, 24-hr. duration storm event *plus* 1 ft. of freeboard.

Location: Constructed in undisturbed soil.

Cross section: Trapezoidal with side slopes 3:1 or flatter.

Control section: Level, straight, at least 20 ft. long.

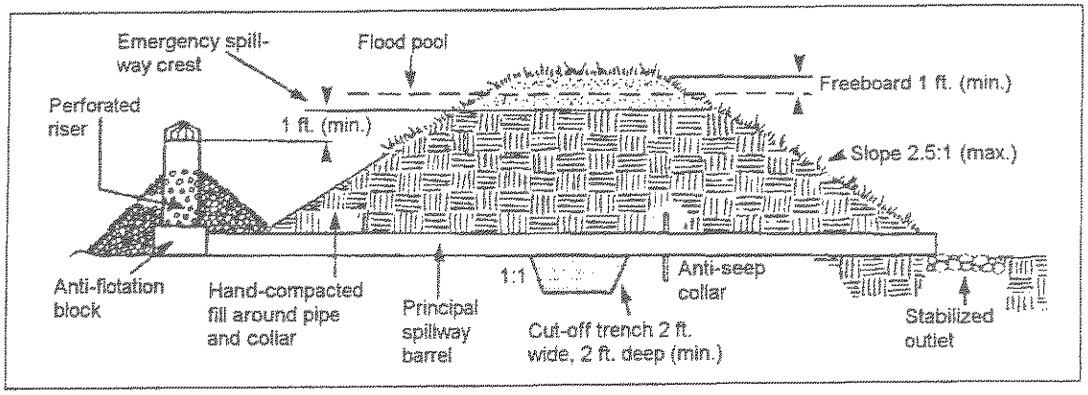


Exhibit 3.72-B. Cross section of a temporary sediment basin principal spillway and embankment.

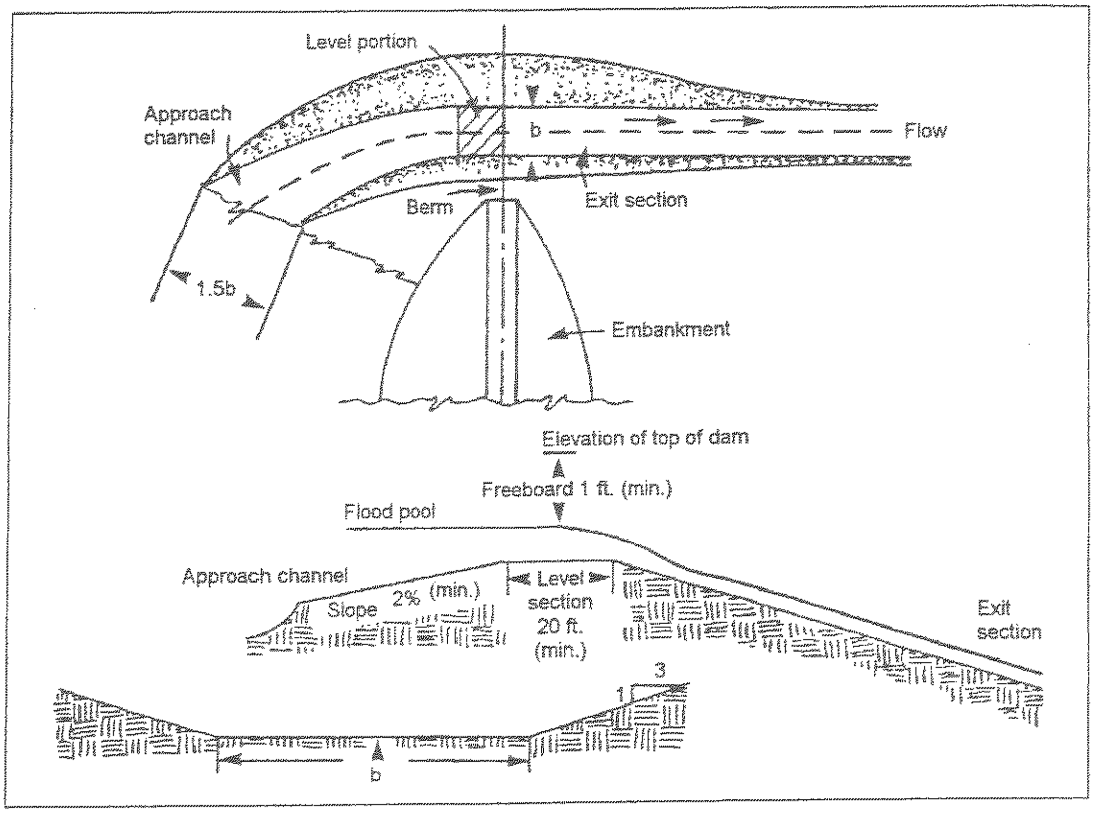


Exhibit 3.72-C. Plan, profile, and cross-section of an emergency spillway for a temporary sediment basin excavated in undisturbed soil.

Installation

SITE PREPARATION:

1. Locate the sediment basin as close to the sediment source as possible, considering soil type, pool area, dam length, and spillway conditions.
2. Clear, grub, and strip the dam location, removing all woody vegetation, rocks, and other objectionable material.
3. Dispose of trees, limbs, logs, and other debris in designated disposal areas.
4. Excavate the area (outlet apron first), stockpiling any surface soil having high amounts of organic matter for later use.
5. Clear the sediment pool to facilitate sediment cleanout.

PRINCIPAL SPILLWAY (see *Exhibit 3.72-B*):

1. Situate the spillway barrel (pipe) and riser on a firm, even foundation.
2. Place around the barrel a 4-in. layer of moist, clayey, workable soil (not pervious material, such as sand, gravel, or silt), and compact by hand to at least the density of the foundation soil. (Don't raise the pipe from the foundation when compacting under the pipe haunches.)
3. Perforate the lower half of the riser in each outside valley with 1/2-in. holes spaced 3 in. apart (or use a manufactured perforated riser).
4. Embed the riser at least 12 in. into concrete (which serves as an anti-flotation block).
5. Surround the riser with 2 ft. of INDOT CA No. 5. stone.
6. Install a trash guard (bars 2-3 in. apart) at the top of the riser.
7. At the pipe outlet, install a riprap apron at least 5 ft. wide and 10 ft. long to a stable grade. (Use well-graded stone with d_{50} of 9 in. minimum.)

EMBANKMENT (see *Exhibit 3.72-B*):

1. Scarify the base of the dam before placing fill.
2. For the dam, use fill from predetermined borrow areas. It should be clean, stable mineral soil free of roots, woody vegetation, rocks, and other debris and must be wet enough to form a ball without crumbling yet not so wet that water can be squeezed out.
3. Place the most permeable soil in the downstream toe and the least permeable in the center portion of the dam.
4. Compact the fill material in 6-8 in. continuous layers over the length of dam. (One way is by routing construction equipment over the dam so that each layer is traversed by at least one wheel of the equipment.)
5. Protect the spillway barrel with 2 ft. of hand-compacted fill before traversing with equipment.
6. Construct and compact the dam to 10% above the design height to allow for settling.
7. Place a reference stake at the sediment cleanout elevation (50% of design volume).

EMERGENCY SPILLWAY (see *Exhibit 3.72-C*):

1. Construct the spillway in undisturbed soil around one end of embankment, and locate it so that any flow will return to the receiving channel without damaging the embankment.
2. Stabilize the spillway as soon as grading is complete; or install paving material to finished grade if the spillway is not to be vegetated.

EROSION CONTROL:

1. Minimize both size of area disturbed and time of exposure.
2. Divert runoff from undisturbed areas away from the basin.
3. Use temporary diversions to prevent surface water from running onto disturbed areas (Practice 3.31).
4. Divert sediment-laden water to upper end of the sediment pool to improve trap effectiveness.
5. Bring all water into the basin at low velocity.
6. Stabilize all disturbed areas (except the lower one-half of the sediment basin) immediately after construction.

SAFETY:

Because sediment basins that impound water are hazardous:

1. Avoid steep slopes; slopes should be 2:1 or flatter.
2. Fence with warning signs if trespassing is likely.
3. De-water the basin between storm events.
4. Follow all state and local requirements on impoundment sites.

Maintenance

(Exhibit 3.72-D)

* Inspect the sediment basin after each storm event.
* Remove and properly dispose of sediment when it accumulates to one-half the design volume (level marked by a reference stake) (see *Exhibit 3.72-D*).
* Periodically check the embankment, emergency spillway, and outlet for erosion damage, piping, settling, seepage, or slumping along the toe or around the barrel; and repair immediately.
* Remove trash and other debris from the riser, emergency spillway, and pool area.
* Clean or replace the gravel around the riser if the sediment pool does not drain properly.
* Remove the basin after the drainage area has been permanently stabilized, inspected, and approved. Do so by draining any water, removing the sediment to a designated disposal area, smoothing the site to blend with the surrounding area, then stabilizing.

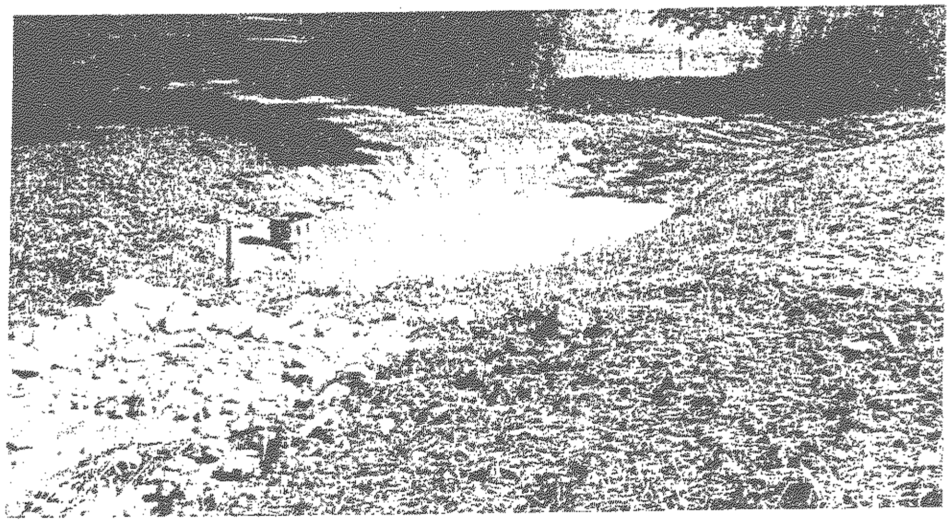


Exhibit 3.72-D. This temporary sediment basin utilizies a barrel riser and a small rock spillway. (Note the reference stake marked to denote half the design volume.)

Common concerns

Piping failure along conduit—caused by improper compaction, omission of anti-seep collar, leaking pipe joints, or use of unsuitable soil.

Erosion of spillway or embankment slopes—caused by inadequate vegetation or improper grading and sloping.

Slumping and/or settling of embankment—caused by inadequate compaction and/or use of unsuitable soil.

Slumping failure—caused by steep side slopes.

Erosion and caving below principal spillway—caused by inadequate outlet protection.

Basin not located properly for access—results in difficult and costly maintenance.

Sediment not properly removed—results in inadequate storage capacity.

Lack of anti-flotation—results in riser damage from uplift.

Lack of trash guard—results in the riser and barrel being blocked with debris.

Principal and emergency spillway elevations too high relative to top of dam—results in overtopping.

Sediment disposal area not designated on design plans—results in improper disposal of accumulated sediment.

Safety and/or health hazard from pond water—caused by gravel clogging the de-watering system.

Principal spillway too small—results in frequent operation of emergency spillway and increased erosion potential.

Practice 3.73
Vegetative Filter Strip (Permanent or Temporary)

A vegetative filter strip is an area between a sediment-producing site and a downslope site or water course that is to be protected from sedimentation.

Purposes
(Exhibit 3.73-A)

* To slow the flow of and remove sediment from surface runoff.
* To reduce the damage associated with sedimentation.
* To improve water quality.

NOTE: Filter strip effectiveness is increased when used in conjunction with other practices, such as sediment barriers, inlet protections, and sediment traps and basins.

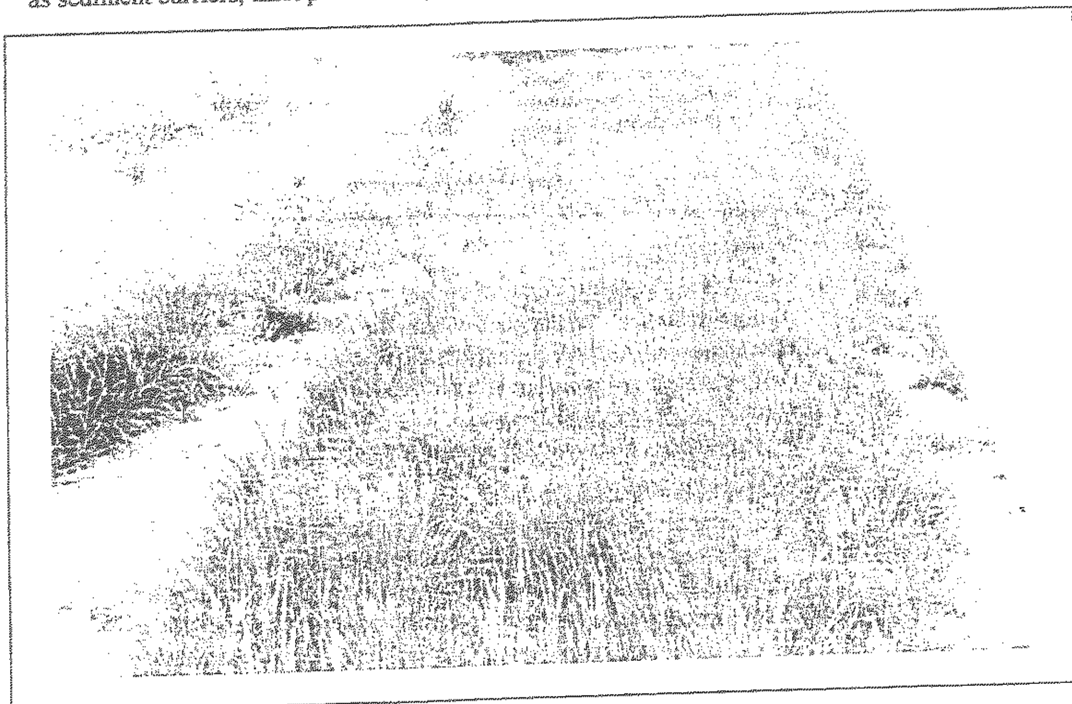


Exhibit 3.73-A. A vegetative filter strip keeps sediment off the road in a new subdivision.

Requirements
(Exhibits 3.73-B, C, and D)

Type: Natural or man-made; permanent or temporary.
Location: Downslope of the sediment-producing site.
Capacity: Concentrated flow depth no greater than 2½ in.
Minimum width: Based on ground slope (see *Exhibit 3.73-B*).
Seed species: Appropriate to soil and other site conditions (see *Exhibits 3.73-C and 3.73-D*).
Cover density: Maintained at a 4-in. or more height.

Exhibit 3.73-B. Minimum Filter Strip Width for Various Percent Slopes.

Ground slope	Minimum width
Less than 1%	10 ft.
1 to 5%	20 ft.
5 to 6%	30 ft.
6 to 9%	40 ft.
9 to 13%	50 ft.
13 to 18%	60 ft.

Exhibit 3.73-D. Seed Species and Rates for Temporary Filter Strips (up to 1 year).

Seed species	Rate per acre
Annual ryegrass	40 lbs.
Wheat or cereal rye	150 lbs.

Exhibit 3.73-C. Seed Species and Minimum Seeding Rates for Permanent Filter Strips on Different Drainage-Capability Soils (over 1 year).

Seed species*	Rate per acre
MODERATELY WELL AND WELL DRAINED SOILS	
Creeping red fescue	15 to 20 lbs.
+ annual ryegrass	5 lbs.
Tall fescue**	30 to 50 lbs.
+ annual ryegrass	5 lbs.
SOMEWHAT POORLY, POORLY AND VERY POORLY DRAINED SOILS	
Tall fescue**	30 to 50 lbs.
+ annual ryegrass	5 lbs.

* Species referenced in *Exhibit 3.12-2* are also suitable for establishment of filter strips.

** Tall fescue provides little cover for, and may be toxic to, some species of wildlife. The IDNR recognizes the need for additional research on alternatives to tall fescue, such as buffalograss, orchardgrass, smooth bromegrass, and switchgrass. This research, in conjunction with demonstration areas, should focus on erosion control characteristics, wildlife toxicity, turf durability, and drought resistance.

Installation

TYPE TO INSTALL:

1. Man-made vs. natural: If the site has little or no vegetative cover and lead time is sufficient (i.e., minimum of 4 weeks during the growing season), seed and establish a filter strip before the upslope area is disturbed; if vegetative cover is already present, simply stop the earth-disturbing activities at the upslope edge of the intended filter strip, leaving the vegetation in the strip intact.
2. Permanent vs. temporary: Consider a permanent filter strip if the area will not be disturbed for at least a year; consider a temporary strip if the area is to be disturbed within a year.

NEW FILTER STRIP:

1. Temporarily divert runoff water away from the site wherever possible (Practice 3.21).
2. Determine necessary width of the filter strip, based on site slope, from *Exhibit 3.73-B*.
3. Prepare the seedbed, and apply lime and fertilizer (Practice 3.12).
4. Plant vegetative species appropriate to the soil and other site conditions as shown in *Exhibit 3.73-C* (temporary strip) and *Exhibit 3.73-D* (permanent strip).
5. Apply mulch or erosion control blankets (Practices 3.15 or 3.17).

EXISTING FILTER STRIP:

1. Determine necessary width of the filter strip, based on site slope, from *Exhibit 3.73-B*.
2. Determine whether the existing vegetation is sufficient for a filter strip.
3. If not and site conditions permit, establish a new filter strip, or overseed the area using a no-till grain drill, or fertilize existing vegetation to enhance growth and density.

Maintenance

* Promptly repair any small rills that form.
* Fertilize and lime as needed to maintain the vegetation in a healthy, growing condition.
* Mow as needed but not shorter than 4 in.
* If a filter strip has actively trapped sediment during construction, periodically re-grade and re-seed the upper portion, since sediment accumulations may cause runoff to concentrate.

Common concerns

Vegetation mowed too short—results in higher runoff velocities and sediment damage.

Strip overwhelmed by sediment from the site above—additional upslope erosion control measures are needed.

Concentrated flow forms rills through strip—install an erosion-resistant liner.

Strip not effectively trapping sediment—width is insufficient for the slope or the vegetative cover lacks density.

Practice 3.74
Silt Fence (Sediment Fence)

Purpose
(Exhibit 3.74-A)

* To retain sediment from small, sloping disturbed areas by reducing the velocity of sheet flow. (NOTE: Silt fence captures sediment by ponding water to allow deposition, not by filtration. Although the practice usually works best in conjunction with temporary basins, traps, or diversions, it can be sufficiently effective to be used alone. A silt fence is not recommended for use as a diversion; nor is it to be used across a stream, channel, or anywhere that concentrated flow is anticipated.)

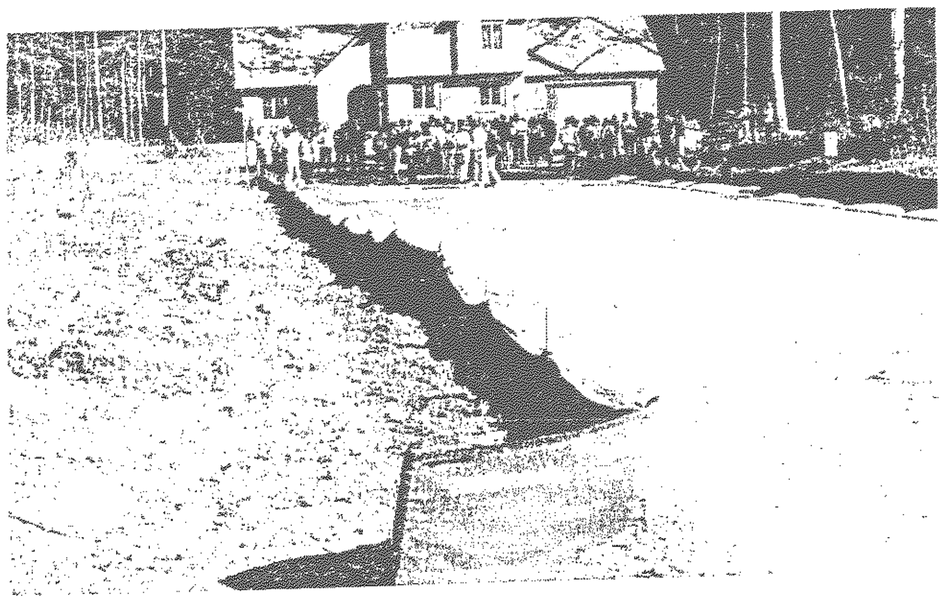


Exhibit 3.74-A. This silt fence protects the street from sediment. The last section of fence is angled toward the vacant lot to prevent runoff from bypassing the fence.

Requirements
(Exhibits 3.74-B and C)

Drainage area: Limited to 1/4 acre per 100 ft. of fence; further restricted by slope steepness (see *Exhibit 3.74-B*).

Location: Fence nearly level, approximately following the land contour, and at least 10 ft. from toe of slope to provide a broad, shallow sediment pool.

Trench: 8 in. minimum depth, flat-bottom or V-shaped, filled with compacted soil or gravel to bury lower portion of support wire and/or fence fabric.

Support posts: 2 x 2-in. hardwood posts (if used) or steel fence posts set at least 1 ft. deep.* (Steel posts should have projections for fastening fabric.)

Spacing of posts: 8 ft. maximum if fence supported by wire, 6 ft. for extra-strength fabric without wire backing.

Fence height: High enough so depth of impounded water does not exceed 1½ ft. at any point along fence line.

Support wire (optional): 14 gauge, 6-in. mesh wire fence (needed if using standard-strength fabric).

Fence fabric: Woven or non-woven geotextile fabric with specified filtering efficiency and tensile strength (see *Exhibit 3.74-C*) and containing UV inhibitors and stabilizers to ensure 6-mo. minimum life at temperatures 0°-120°F.

Exhibit 3.74-B. Maximum Land Slope and Distance for Which a Silt Fence Is Applicable.

Land slope	Max. distance above fence
Less than 2%	100 ft.
2 to 5%	75 ft.
5 to 10%	50 ft.
10 to 20%	25 ft.
More than 20%	15 ft.

* Some commercial silt fences come ready to install, with support posts attached and requiring no wire support.

Exhibit 3.74-C. Specifications Minimums for Silt Fence Fabric.

Physical property	Woven fabric	Non-woven fabric
Filtering efficiency	85%	85%
Tensile strength at 20% elongation:		
Standard strength	30 lbs./linear in.	50 lbs./linear in.
Extra strength	50 lbs./linear in.	70 lbs./linear in.
Slurry flow rate	0.3 gal./min./sq.ft.	4.5 gal./min./sq.ft.
Water flow rate	15 gal./min./sq.ft.	220 gal./min./sq.ft.
UV resistance	70%	85%

Outlet (optional): To allow for safe storm flow bypass with-out overtopping fence (see *Exhibit 3.74-D*). Placed along fence line to limit water depth to 1½ ft. maximum; crest—1 ft. high maximum; weir width--4 ft. maximum; splash pad—5 ft. wide, 5 ft. long, 1 ft. thick minimum.

Installation

(Exhibits 3.74-D, E, and F)

SITE PREPARATION:

1. Plan for the fence to be at least 10 ft. from the toe of the slope to provide a sediment storage area.
2. Provide access to the area if sediment cleanout will be needed.

OUTLET CONSTRUCTION (OPTIONAL) (see *Exhibit 3.74-D*):

1. Determine the appropriate location for a reinforced, stabilized bypass flow outlet (unless the fence is designed to retain all runoff from a 2-yr. frequency, 24-hr. duration storm event).
2. Set the outlet elevation so that water depth cannot exceed 1½ ft. at the lowest point along the fence line.
3. Locate the outlet weir support posts no more than 4 ft. apart, and install a horizontal brace between them. (Weir height should be no more than than 1 ft. and water depth no more than 1½ ft. anywhere else along the fence.)
4. Excavate the foundation for the outlet splash pad to minimums of 1 ft. deep, 5 ft. wide, and 5 ft. long on level grade.
5. Fill the excavated foundation with INDOT CA No. 1 stone, being careful that the finished surface blends with the surrounding area, allowing no overfall.
6. Stabilize the area around the pad.

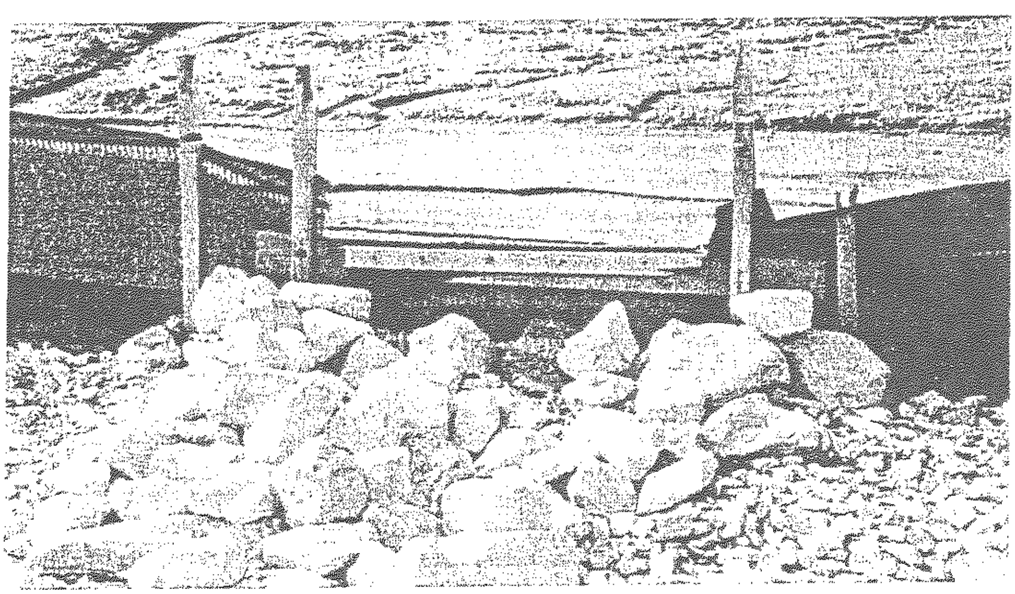


Exhibit 3.74-D. Overflow weir for a silt fence outlet.

FENCE CONSTRUCTION (see *Exhibit 3.74-E*):

1. Along the entire intended fence line, dig an 8-in. deep flat-bottomed or V-shaped trench.
2. On the downslope side of the trench, drive the wood or steel support posts at least 1 ft. into the ground (the deeper the better!), spacing them no more than 8 ft. apart if the fence is supported by wire or 6 ft. if extra-strength fabric is used without support wire. Adjust spacing, if necessary, to ensure that posts are set at the low points along the fence line. (NOTE: If the fence has pre-attached posts or stakes, drive them deep enough so the fabric is satisfactorily in the trench as described in Step 6.)
3. Fasten support wire fence (if the manufacturer recommends its use) to the upslope side of the posts, extending it 8 in. into the trench.
4. Run a continuous length of geotextile fabric in front (upslope) of the support wire and posts, avoiding joints, particularly at low points in the fence line.
5. If a joint is necessary, nail the overlap to the nearest post with lath (see *Exhibit 3.74-F*).
6. Place the bottom 1 ft. of fabric in the 8-in. deep trench, extending the remaining 4 in. toward the upslope side.
7. Backfill the trench with compacted earth or gravel.

   NOTE: If using a pre-packed commercial silt fence rather than constructing one, follow manufacturer's installation instructions.

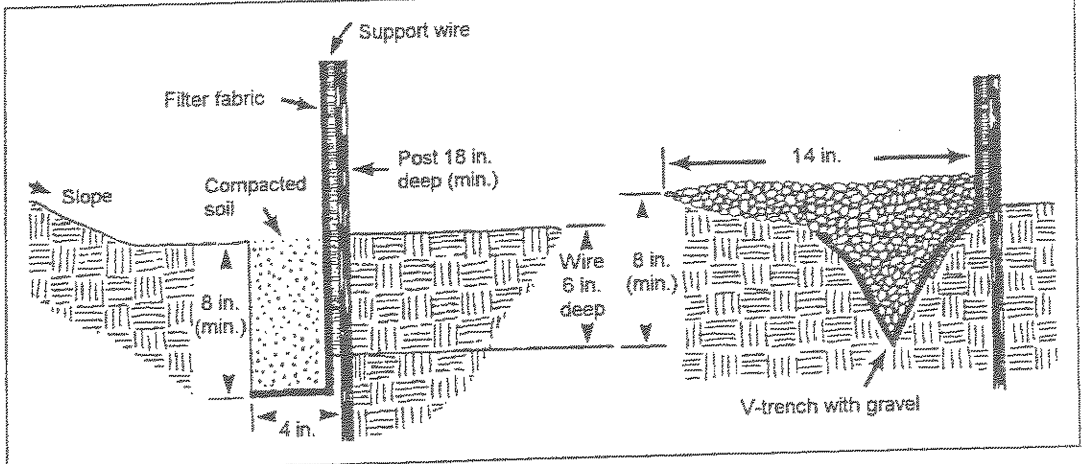


Exhibit 3.74-E. Detailed example of silt fence installation (showing flat-bottom and V-shaped trenches).

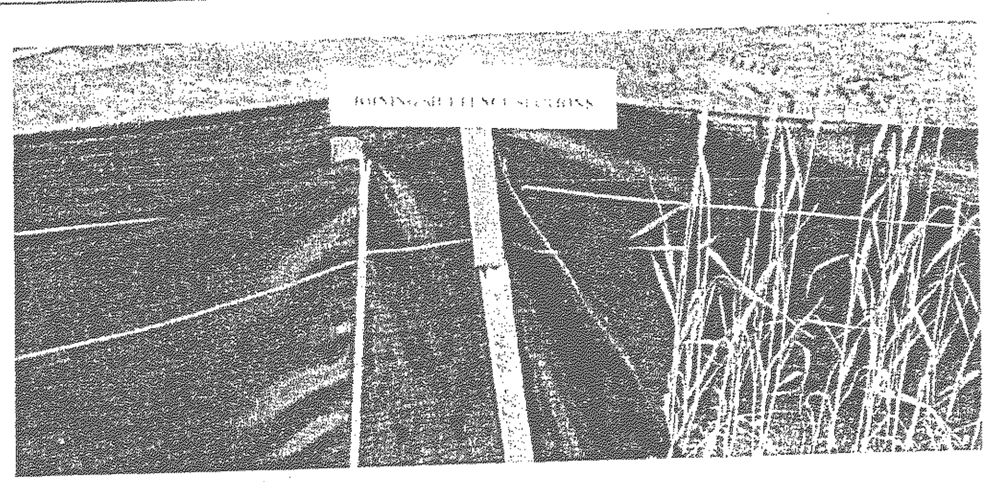


Exhibit 3.74-F. Detail of a silt fence joint.

Maintenance

* Inspect the silt fence periodically and after each storm event.
* If fence fabric tears, starts to decompose, or in any way becomes ineffective, replace the affected portion immediately.

* Remove deposited sediment when it reaches half the height of the fence at its lowest point or is causing the fabric to bulge.
* Take care to avoid undermining the fence during clean out.
* After the contributing drainage area has been stabilized, remove the fence and sediment deposits, bring the disturbed area to grade, and stabilize.

Common concerns

(Exhibit 3.74-G)

Fence sags or collapses—because drainage area was too large, too much sediment accumulated before cleanout, approach slope was too steep, or the fence was not adequately supported.

Fence undercut or blown out at the bottom by excessive runoff—because the fence bottom was not properly buried at all points, the trench was not backfilled with compacted earth or gravel, the fence was installed on excessive slope, or the fence was located across a drainageway.

Fence overtopped—because the sediment storage area was inadequate, no provision was made for safe bypass of storm flow, or the fence was located across a drainageway.

Erosion occurs around end of fence—because the fence terminated at an elevation below the top of the sediment storage pool, the fence terminated in an unstabilized area, or the fence was installed on excessive slope.

Dense soil layers exposed by excavation or caused by equipment compaction—cause difficulty in driving wooden posts to sufficient depth; solve by using steel posts.

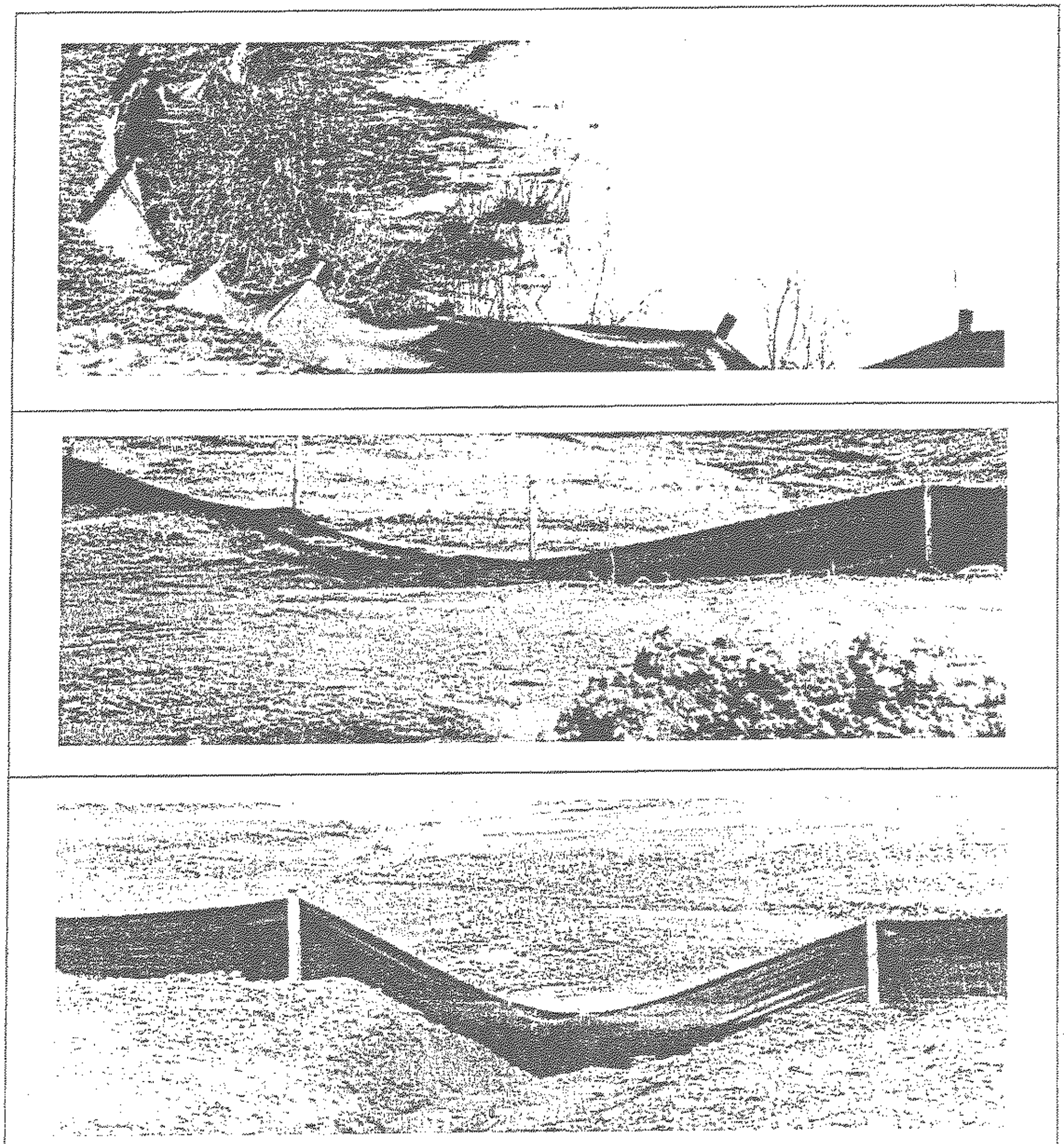


Exhibit 3.74-G. Concentrated flow and excessive drainage area caused these silt fences to fail.

Practice 3.75
Straw Bale Dam (Straw Bale Filter)

Purpose
(Exhibit 3.75-A)

* To retain sediment from small, sloping disturbed areas by reducing the velocity of sheet flow. (NOTE: This practice should not be used as a diversion nor used in a stream, channel, or anywhere that concentrated flow is anticipated; nor is it recommended for paved surfaces because of the lack of an anchoring system.)

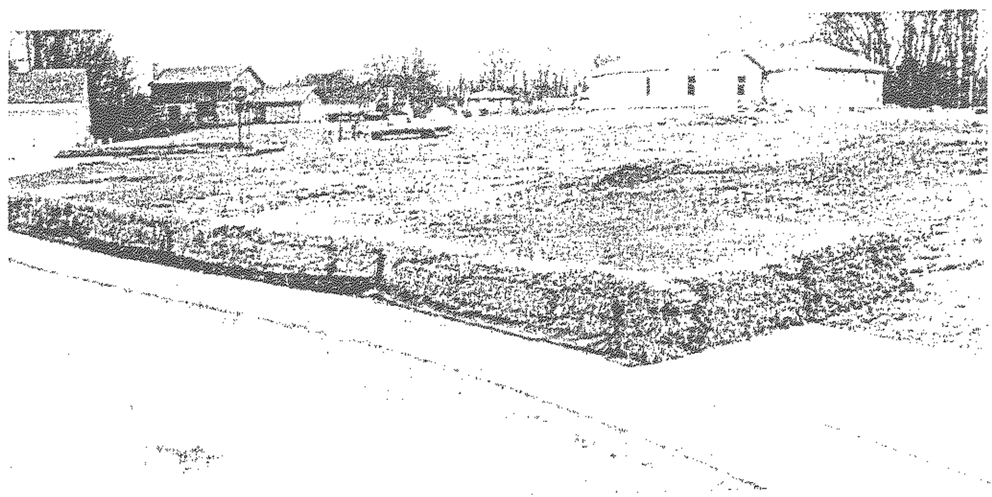


Exhibit 3.75-A. This straw bale dam is preventing sediment runoff from a lot under development. The sidewalk is not yet installed where the bales are staked.)

Requirements
(Exhibit 3.75-B)

Effective life: Less than 3 months.

Sheet flow drainage area: Limited to 1/4 acre per 100 ft. of dam; further restricted by slope steepness as shown in *Exhibit 3.75-B*.

Minor swale drainage area: Less than 2 acres.

Location: Nearly level, and as nearly as possible on the land contour, and at least 10 ft. from toe of slope to provide a broad, shallow sediment pool. (May run slightly off level if it terminates in a level section with a stabilized outlet, diversion, sediment basin or trap.)

Anchoring system: Two 36-in. long (minimum) steel rebars or 2 x 2-in. hardwood stakes driven through each bale.

Bale size: 14 in. x 18 in. x 36 in. minimum.

Exhibit 3.75-B. Maximum Land Slope and Distances Above a Straw Bale Dam.

Land slope	Maximum distance above dam
Less than 2%	100 ft.
2-5%	75 ft.
5-10%	50 ft.
10-20%	25 ft.
More than 20%	15 ft.

Installation
(Exhibit 3.75-C)

1. Excavate a trench at least 4 in. deep, a bale's width, and long enough that the end bales are somewhat upslope of the sediment pool (so no flow can cut around them).
2. Place each bale in the trench so the bindings are oriented around the sides rather than top and bottom (to minimize binding deterioration), and abut the bales tightly against each other.

3. Anchor the dam by driving two 36-in. long steel rebars or 2 x 2-in. hardwood stakes through each bale until nearly flush with the top. (Drive the first stake toward the previously laid bale to force the bales together.)
4. Chink (i.e., tightly wedge) straw into any gaps between the bales to prevent sediment-laden water from running through.
5. Backfill and compact the excavated soil against the bales to ground level on the downslope side and to 4 in. above ground level on the up-slope side.

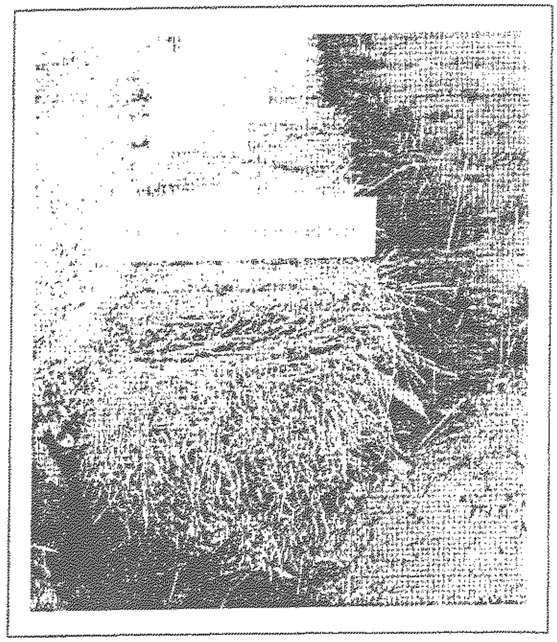


Exhibit 3.75-C. Cross-section of an installed straw bale dam.

Maintenance

* Inspect straw bale dams after each storm event, and remove any sediment deposits promptly (to ensure adequate storage volume for the next rain), taking care not to undermine the entrenched bales.
* Also inspect periodically for deterioration or damage from construction activities, and repair immediately.
* After the contributing drainage area has been stabilized, remove all straw bales and sediment, bring the disturbed area to grade, and stabilize it.

Common concerns

(Exhibit 3.75-D)

Erosion around end of bales—because the dam terminates at an elevation below the top of the temporary pool or at an unstabilized area, or is located on excessive slope, or was placed in an area of concentrated flow.

Dam over-topped—because storage capacity is inadequate, no provision was made for safe by-pass of storm flow, or the drainage area was too large.

Dam undercut—because the bales were not entrenched at least 4 in. and backfilled with compacted soil or were not abutted or chinked properly, or the drainage area was too large, or the dam was placed in an area of concentrated flow (see *Exhibit 3.75-D*).

Dam collapses or dislodges—because the bales were not adequately staked, the drainage area was too large, too much sediment was allowed to accumulate before clean-out, approach was too steep, the bales deteriorated.

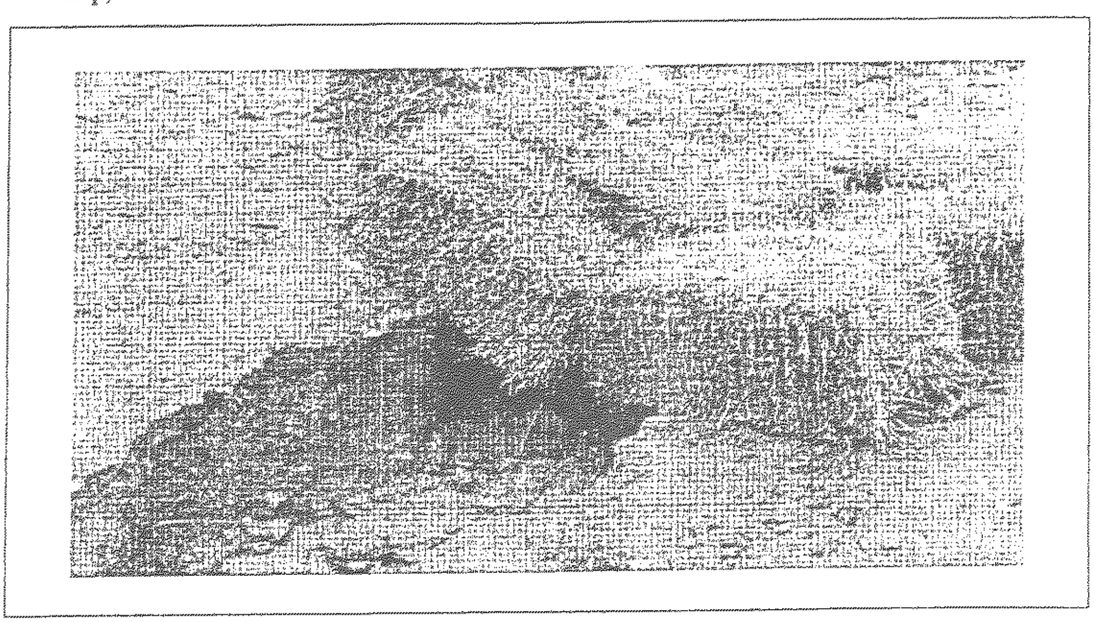


Exhibit 3.75-D. A straw bale dam is ineffective in a channel of concentrated flow.

Practice 3.76
Rock Dam

Purpose
(Exhibit 3.76-A)

* To prevent off-site sedimentation by trapping sediment on the construction site. (NOTE: This practice is useful where earth fill material is not readily available.)

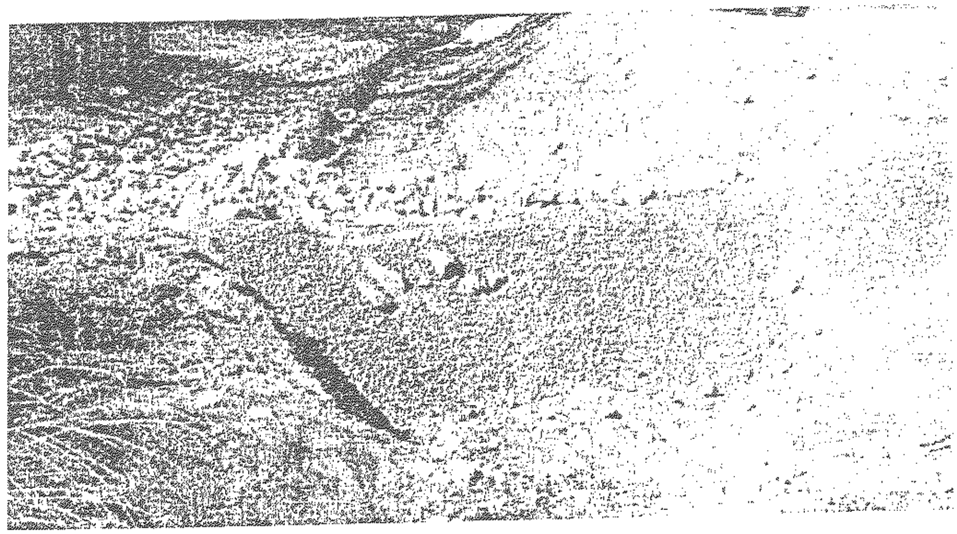


Exhibit 3.76-A. Rock dam with a spillway to keep discharge velocity low.

Requirements
(Exhibits 3.76-B and C)

Contributing drainage area: 50 acres maximum.
Design life: Limited to 3 yrs.
Sediment storage: 1,800 cu.ft./acre disturbed (minimum) measured 1 ft. below spillway crest.
Basin shape: Minimum 2:1 length-to-width ratio.
Basin area: Variable; the larger the surface area the greater the trapping efficiency.
Dam crest height: Limited to 8 ft.
Spillway capacity: Peak runoff from a 10-yr. frequency, 24-hr. duration storm event, a maximum flow depth of 1 ft. and minimum freeboard of 1 ft. (Entire length of dam between rock abutments may serve as spillway.)
Dam dimensions: Top width, 5 ft. minimum; side slopes, 2:1 or flatter upstream, 3:1 or flatter downstream.
Earth abutments: Smooth, stable, 2:1 or flatter slopes.
Rock abutments (to protect earth abutments): Extended along downstream face to toe of dam and at least 1 ft. higher than spillway face at all points, 2 ft. above spillway crest, and 1 ft. thick, with 2:1 or flatter side slopes.
Outlet protection: Rock apron, 1½ ft. thick (minimum), zero grade, with length equal to height of dam or extended to stable grade, whichever is greater.
Rock material: INDOT revetment riprap.
Protection from piping: Geotextile fabric for separation and filtration covering entire foundation, including earth abutments and apron.
Basin de-watering: Through a 1-ft. thick layer of INDOT CA No. 5 stone on upstream face of the dam.

Installation

SITE PREPARATION:
1. Divert runoff from undisturbed areas away from the rock dam and basin area.
2. Excavate the foundation for the apron, using it as a temporary sediment basin during construction of the dam.

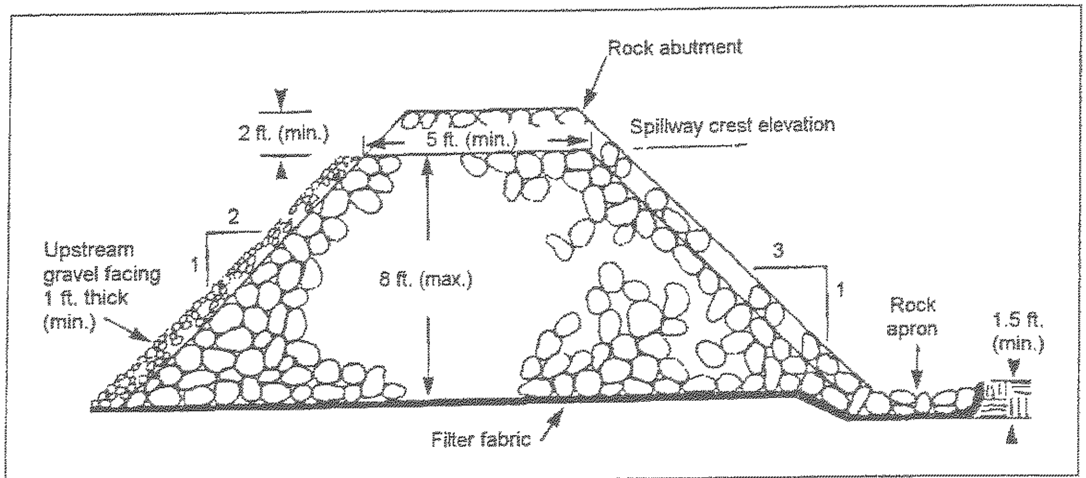


Exhibit 3.76-B. Cross-section of a rock dam.

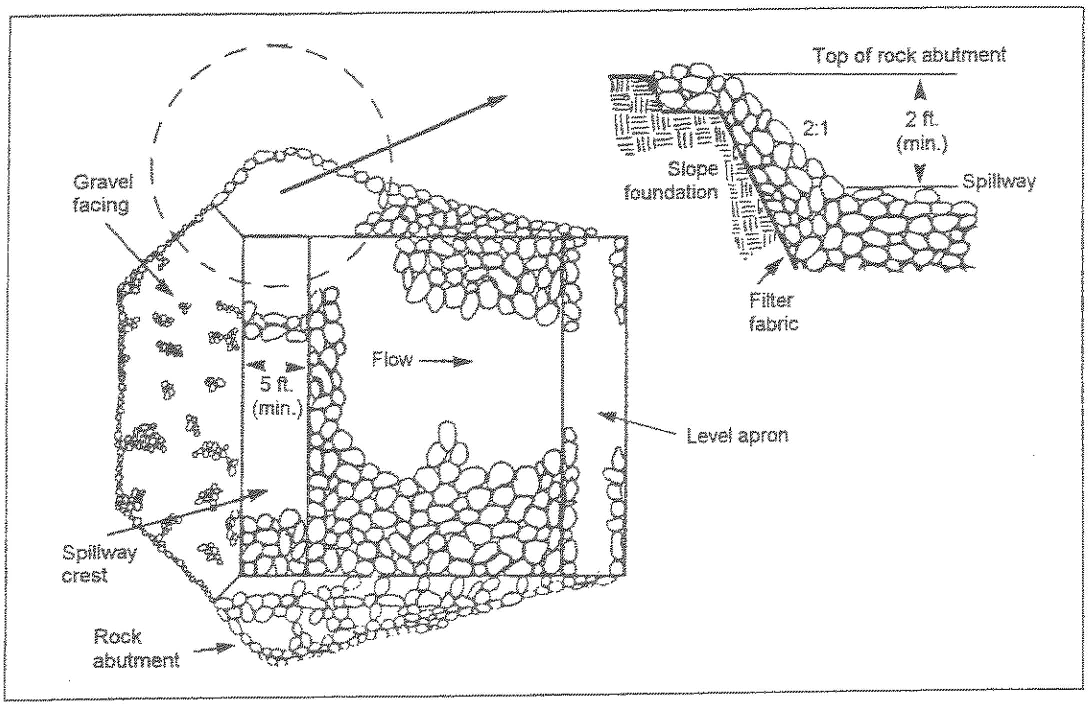


Exhibit 3.76-C. Plan view of a rock dam with spillway detail.

3. Clear and grub the area under the dam, removing and properly disposing of all root mat, brush, and other debris.
4. Grade the earth abutments no steeper than 2:1.

DAM AND BASIN CONSTRUCTION (see *Exhibits 3.76-B* and *C*):

1. Excavate a cutoff trench at the center line of the dam, extending all the way up the earth abutments, and backfill with compacted earth fill.
2. Smooth the dam foundation.
3. Cover the entire foundation, including both earth abutments, with geotextile fabric, making sure the upstream strips overlap the downstream strips at least 1 ft.
4. Construct the dam to planned dimensions.
5. Once the dam is in place, clear the sediment basin area, properly disposing of the cleared material.
6. Set a marker stake to indicate the cleanout elevation (i.e., point at which the basin is 50% full of sediment).
7. Divert construction site runoff flow into the upper end of the basin using temporary diversions (Practice 3.21).
8. Stabilize all disturbed areas except the lower half of the basin.

SAFETY PRECAUTIONS:

1. Because sediment basins that impound water are hazardous, (a) be sure side slopes are 2:1 or flatter, (b) fence with warning signs if trespassing is likely, (c) de-water the basin between storm events, and (d) follow all state and local impoundment site requirements.

Maintenance

* Inspect the rock dam and basin after each storm event.
* Remove sediment when it accumulates to half the design volume (marked by a stake).
* Check the dam and abutments for erosion, piping, or rock displacement, and repair immediately.
* If the basin does not drain between storms, replace the stone on the upstream face of the dam.
* If the basin drains too rapidly following a storm (i.e., less than 6 hrs.), add INDOT CA No. 5 gravel on the upstream face of the dam.
* Once the contributing drainage area has been permanently stabilized, (a) remove water and sediment from the basin; (b) remove the dam, disposing of the rock in designated disposal areas; (c) smooth the site to blend with the surrounding area; and (d) stabilize.

Common concerns

Failure from piping along abutments—because the filter material was not properly installed or the earth abutments are too steep.

Stone displacement from face of dam—because stone size is too small or the face is too steep.

Erosion below dam—because the apron was not extended to stable grade.

Erosion of abutments during spillway flow—because the rock abutment is not high enough.

Sediment carried through spillway—because the drainage area is too large; to solve, divert runoff from the undisturbed area away from the basin.

Sediment loss through dam—because the layer of aggregate on the upstream face is not thick enough or is too coarse to restrict flow through the dam.

APPENDIX C

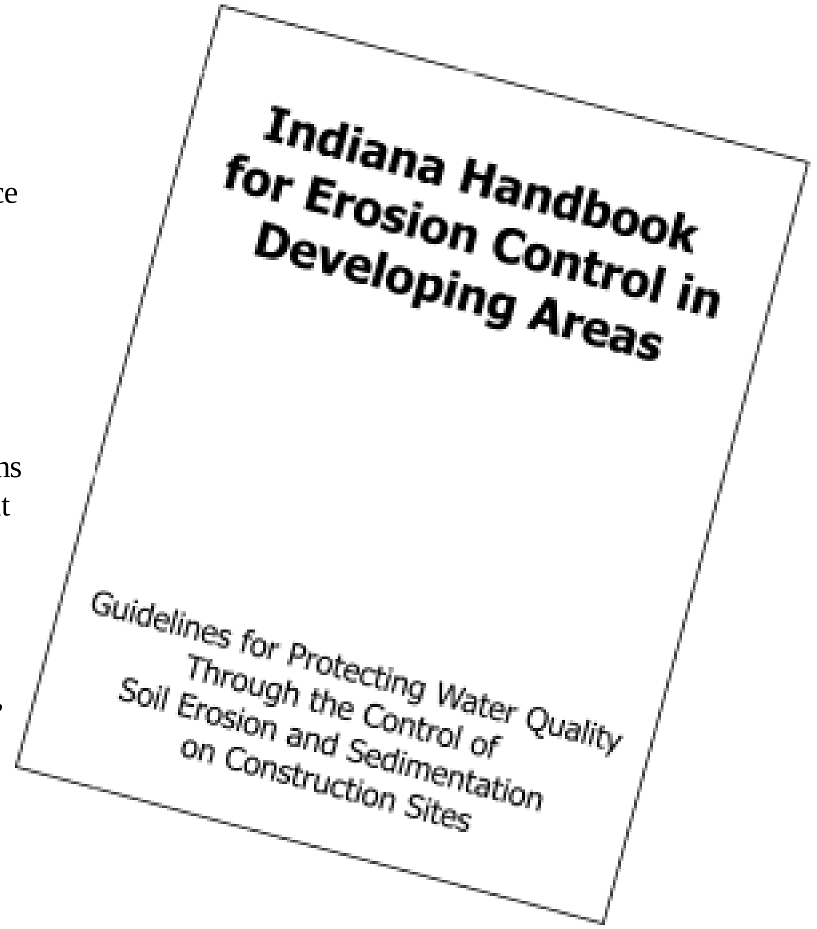
IDNR BROUCHURE: EROSION AND SEDIMENT CONTROL FOR INDIVIDUAL BUILDING SITES

Additional References

Other resources are available to assist you in taking better care of your construction site.

Indiana Handbook for Erosion Control in Developing Areas

Provides installation instructions on five of the more commonly used building site erosion and sediment control practices. Available from the Indiana Department of Natural Resources, Customer Service Center, 402 West Washington Street, W-160, Indianapolis, IN 46204, 317/232-4200.



Indiana Handbook for Erosion Control in Developing Areas

Guidelines for Protecting Water Quality Through the Control of Soil Erosion and Sedimentation on Construction Sites

Soil Surveys

Another valuable reference when building a home is your county's detailed soil survey report, which contains information about soil hazards and limitations (*such as wetness*) that may need to be addressed at the time of the construction. Single copies of soil surveys are available at your local Soil and Water Conservation District (SWCD) office or the USDA Natural Resources Conservation Service, 6013 Lakeside Boulevard, Indianapolis, IN 46278-2933, 317/290-3200 or 317/290-3225 *FAX*.

Division of Soil Conservation
Indiana Department of Natural Resources
402 West Washington Street, Room W-265
Indianapolis, IN 46204-2782
317/233-3870
317/233-3882 FAX
www.state.in.us/dnr/soilcons

Revised September 2001

DNR Division of Soil Conservation

Erosion & Sediment Control for Individual Building Sites

Soil erosion and resulting sedimentation are a leading cause of water quality problems in Indiana. Although erosion has long been associated with agricultural activities, it is also a major concern at construction sites, if the disturbed land is left unprotected. Every phase of a construction project has the potential of contributing significant quantities of sediment-laden runoff. Therefore, as a site is developed, all who are associated with a project must do their part to control erosion.

The developer is the primary entity having responsibility for controlling erosion, sedimentation, and stormwater runoff associated with the overall construction project. He or she is expected to install effective sediment control practices and implement an aggressive seeding program to address erosion and sedimentation. A seeding program can provide a financial benefit to the developer because studies have shown vegetated lots typically have a higher sale potential than un-vegetated lots. One of the main components during the initial phases of construction is the installation of the infrastructure (e.g., roads, utilities, and stormwater management systems). As the infrastructure is installed, it gradually transforms into a very efficient conveyor of stormwater runoff and the associated pollutants. In many communities, developers are expected to use appropriate stormwater management practices that will reduce the impact of increased runoff associated with the construction project.

This pamphlet addresses erosion and sediment control on an individual building lot, typically one acre or less in size.

The final phase of most projects is the construction that takes place on building sites. As individual lot construction progresses, residents and businesses begin to occupy buildings that have been completed. Sedimentation in roads, streets, and stormwater drainage systems may now become a nuisance and potential safety hazard to businesses and their clientele as well as residents of the development. The severity of these impacts is often directly related to the intensity of individual lot construction. Once independent construction activities commence on an individual residential or commercial building lot(s), the developer does not necessarily maintain the authority or responsibility to address erosion, sedimentation, and stormwater runoff. Often times these responsibilities are passed onto the individual lot owners and/or their respective contractors.

This pamphlet addresses erosion and sediment control on an individual building lot, typically one acre or less in size. First, it looks at some consequences of construction site erosion and presents four principles important for control. Next, it addresses the issue of proper lot drainage. Then it presents the seven steps within a construction sequence that should result in effective erosion control. Also included are installation instructions for several commonly used building site erosion and sediment control practices, as well as suggested reference materials and sources for further assistance.

Primary Concerns Related to Erosion and Sedimentation

Water Quality

Sediment is the number one pollutant, by volume, of surface waters in the state of Indiana. It impacts water quality by degrading the habitat of aquatic organisms and fish, by decreasing recreational value, and by promoting the growth of nuisance weeds and algae.

Flooding

Sediment accumulation in streams, lakes, and rivers reduces their capacity to contain stormwater, which can result in increased flooding.

Local Taxes

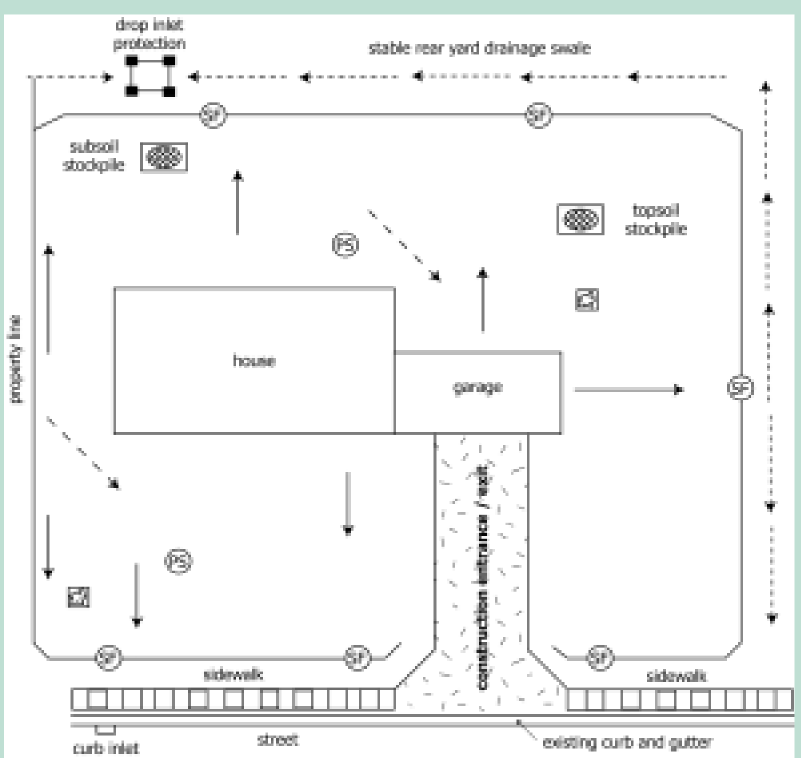
Sediment that finds its way into streets, storm sewers, and ditches results in additional maintenance costs for local, state, and federal governments.

Property Values

Sediment deposits not only impair water quality but also damage property, thus reducing its use and value.

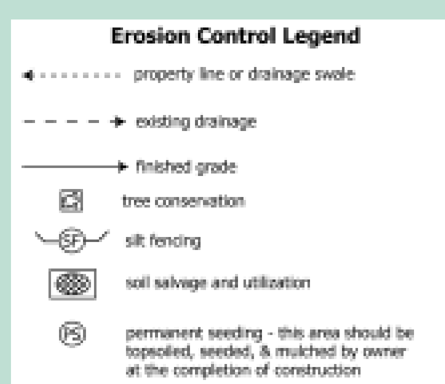
Sample Erosion / Sediment Control Plan

Every building site is unique and poses its own potential erosion hazards. In many instances, additional or alternative control methods are necessary if the lot is adjacent to a creek, lake, or wetland; slopes are greater than six percent; receives runoff from adjacent areas; and/or more than one acre of ground is disturbed.

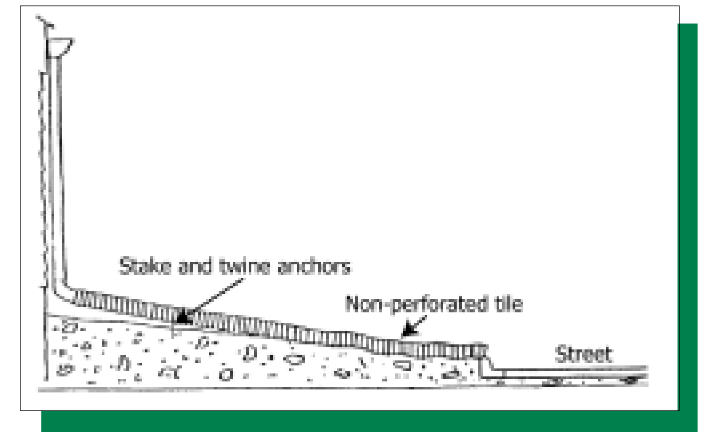


NOTES:

1. *It is the responsibility of the property owner and contractor to comply with State laws and local and county ordinances regarding construction site erosion and sediment control.*
2. *This plan is only a sample plan and is not intended to be all inclusive or address every situation, additional or modified practices may be required on some sites.*
3. *Erosion or sediment control measures must be functional and maintained throughout construction.*
4. *Maintain positive drainage away from the structure(s).*



Temporary Downspout Extenders

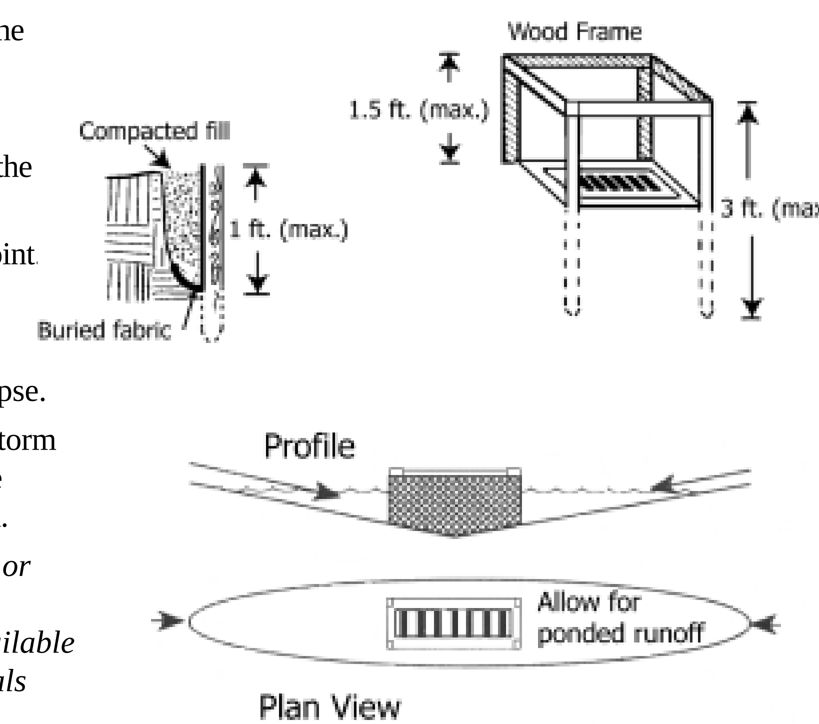


1. Install extenders as soon as gutters and downspouts are installed to prevent erosion from roof runoff.
2. Use non-perforated (un-slotted) drainage tile.
3. Route water to a stable grassed or paved area or to the storm sewer. Do not route water directly to a street or sidewalk in the winter due to the formation of ice.
4. Remove downspout extenders after vegetation is established.

Drop Inlet Protection

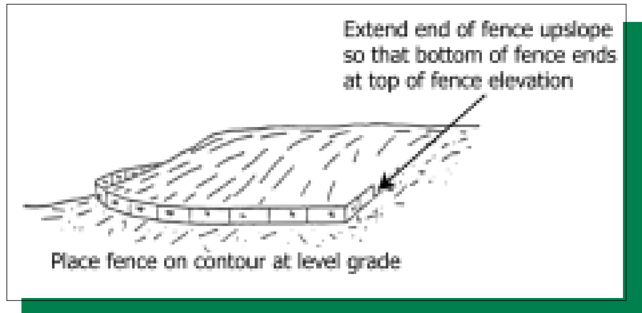
1. Construct a six-inch dike on the down slope side to prevent bypass flow.
2. Dig a trench eight inches deep and four inches wide.
3. Space support posts evenly against the inlet perimeter a maximum of four feet apart, and drive them about 1.5-feet into the ground.
4. Cut enough filter fabric from a single roll to eliminate joints.
5. Using lath and nails, fasten the fabric to the posts.
6. Place 12-inches of fabric in the trench, extending the bottom four inches toward the upslope side.
7. Join silt fence sections by using a wrap joint.
8. Backfill trench with soil materials and compact.
9. Cross brace the corners to prevent collapse.
10. Inspect at least weekly and after each storm event, and repair as needed, and remove accumulated sediments after every storm.

Note: Either follow the directions above, or utilize a pre-manufactured drop inlet protection device. These products are available commercially in a wide variety of materials and designs.



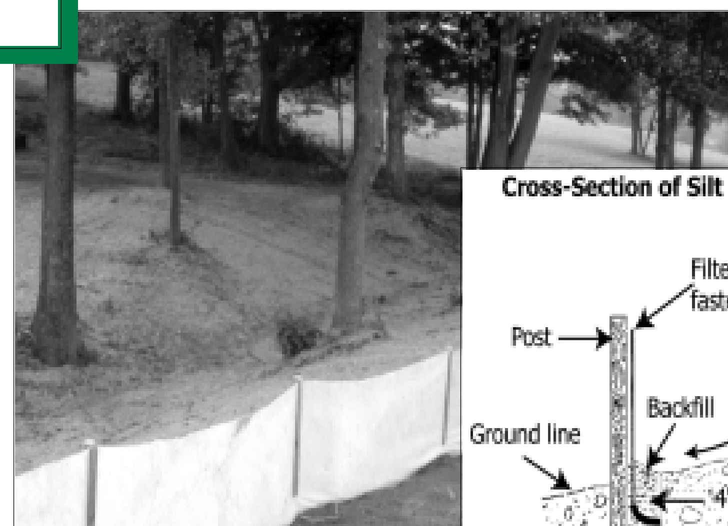
Erosion & Sediment Control Practices

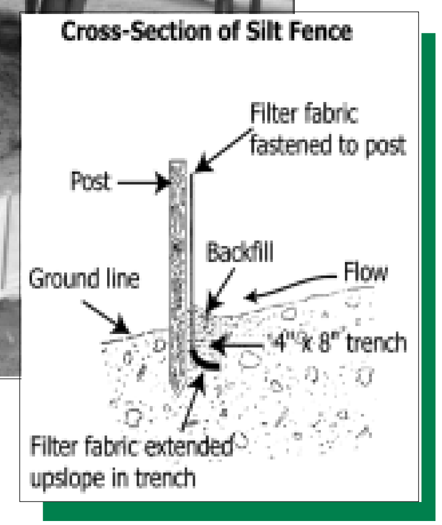
Silt Fences



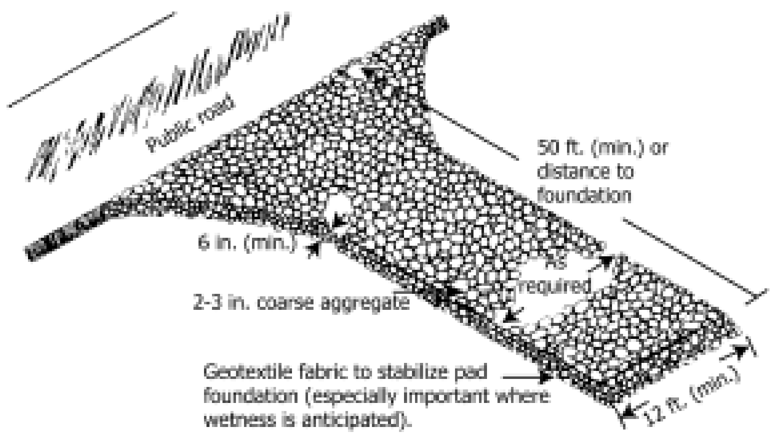
1. Install silt fence parallel to the contour of the land.
2. Extend ends upslope to allow water to pond behind fence.
3. Excavate a trench 4-inches wide, 8-inches deep.
4. Install fence with posts on the down slope side.
5. Place 12-inches of fabric in the trench, extending the bottom four inches toward the upslope side.
6. Join silt fence sections by using a wrap joint.
7. Backfill trench with soil materials and compact.
8. Inspect at least weekly and after each storm event, repairing as needed and removing sediment deposits when they reach one-half the fence height.

Note: Silt fence has a life expectancy of six months to one year, whereas straw bale barriers have a limited life of three months or less.





Gravel Construction Entrances



1. Place six inches of coarse aggregate (INDOT CA No. 2) over a stable subgrade.
2. Construct the drive at least 12-feet wide and 50-feet long or the distance to the foundation.
3. Add stone as needed to maintain six inches of clean depth.
4. To improve stability or if wet conditions are anticipated, place geotextile fabric on the graded foundation.

Controlling Building Site Erosion & Sedimentation

Erosion control is important on any building site regardless of its size. Usually, principles and methods for controlling erosion and reducing off-site sedimentation are relatively simple and inexpensive. Here are four basic steps to follow when developing a building site.

Evaluate the Site

Inventory and evaluate the resources on the lot before building. Location of structures should be based on the lot's natural features. Identify trees that you want to save and vegetation that will remain during construction. Also identify areas where you want to limit construction traffic. Wherever possible, preserve existing vegetation to help control erosion and off-site sedimentation.

Select & Install Initial Erosion/ Sediment Control Practices

Determine the specific practices needed, and install them before clearing the site. Among the more commonly used practices are vegetative filter strips, silt fences, gravel drives, and inlet protection.

Develop a Practice Maintenance Program

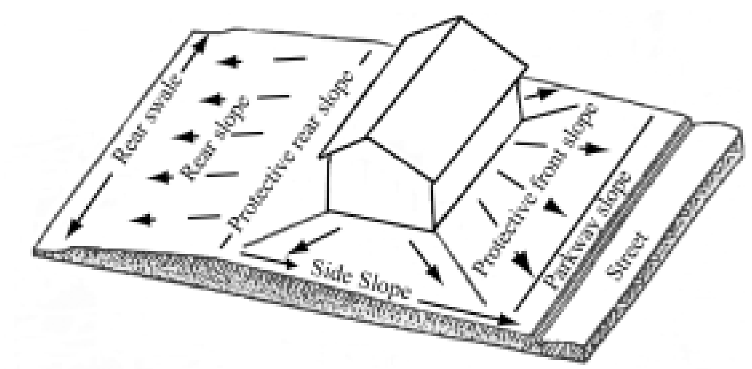
Maintenance of all practices is essential for them to function properly. Practices should be inspected twice a week and after each rainfall event. When a problem is identified, repair or replace the practice immediately. If frequent repairs are required, another more substantial practice may need to be selected. In addition, any sediment that is tracked onto the street should be scraped and deposited in a protected area. Do not flush sediment from the street with water.

Revegetate the Site

Establish vegetation as soon as possible. A well-maintained lot has a higher sale potential.

Building Lot Drainage

The best time to provide for adequate lot drainage is before construction begins. With proper planning, most drainage problems can be avoided. That's important because correcting a problem after it occurs is usually much more difficult and costly. Here's what it takes to ensure good lot surface and subsurface drainage.



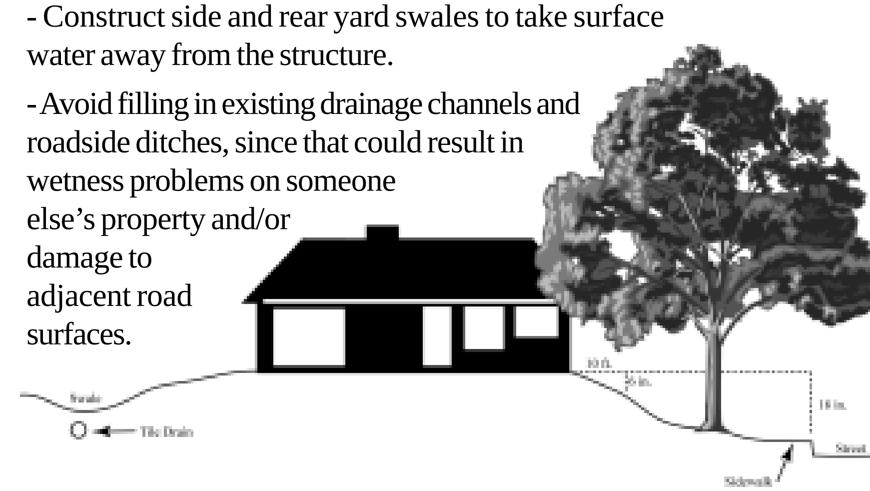
Surface Drainage

- Position the structure a minimum of 18 inches above street level.

- Divert stormwater runoff away from the structure by grading the lawn to provide at least six inches of vertical fall in the first ten feet of horizontal distance.

- Construct side and rear yard swales to take surface water away from the structure.

- Avoid filling in existing drainage channels and roadside ditches, since that could result in wetness problems on someone else's property and/or damage to adjacent road surfaces.



Subsurface Drainage

- Provide an outlet for foundation or footer drains and for general lot drainage by using storm sewers (*where allowed*), or obtain drainage easements if you must cross adjoining properties.

- If you accidently cut through an existing field tile, assume that it carries water even if currently dry; therefore, reroute (*using the same size tile*) around the structure or septic field, then reconnect it.

Construction Sequence for Erosion & Sediment Control

1 Evaluate the Site

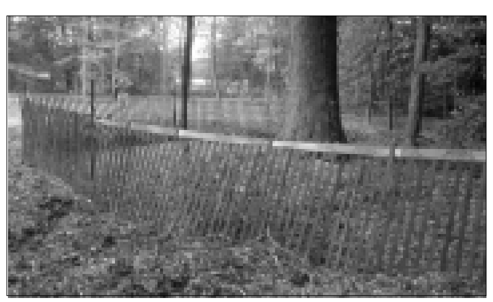
Before construction, evaluate the site; mark vegetative areas and trees to be protected, unique areas to preserve, on-site septic system absorption fields, and vegetation suitable for filter strips, especially in perimeter areas.

Identify Vegetation to be Saved

Select and identify the trees, shrubs and other vegetation to be saved (*see Step 2: "Vegetative Filter Strips"*).

Protect Trees & Sensitive Areas

- To prevent root damage, do not grade, burn, place soil piles, or park vehicles near trees or in areas marked for preservation.
- Place plastic mesh or snow fence barriers around the trees' driplines to protect the area below their branches.
- Place a physical barrier, such as plastic fencing, around the area designated for a septic system absorption field (*if applicable*).



2 Install Perimeter Erosion and Sediment Controls

Identify the areas where sediment-laden runoff could leave the construction site, and install perimeter controls to minimize the potential for off-site sedimentation. It's important that perimeter controls are in place before any earth-moving activities begin.

Protect Down-Slope Areas with Vegetative Filter Strips

- On slopes of less than six percent, preserve a 20-to 30-foot wide (minimum) vegetative buffer strip around the perimeter of the property, and use it as a filter strip for trapping sediment.
- Do not mow filter strip vegetation shorter than four inches.

Protect Down-Slope Areas with Silt Fences and Other Appropriate Practices

- Use silt fencing along the perimeter of the lot's downslope side(s) to trap sediment. *Refer to silt fences practices.*

Install Gravel Drive

- Restrict all lot access to this drive to prevent vehicles from tracking mud onto roadways. Refer *to gravel construction entrances.*

Protect Storm Sewer Inlets

Curb inlet protection devices are not efficient in removing sediment from stormwater runoff. Additional erosion and sediment control measures must be incorporated into the plan and the day-to-day construction operations to minimize the amount of sediment entering a street. The best defense in controlling sedimentation is the installation of perimeter protection downslope of the construction activity using gravel construction entrances and daily cleaning and removal of sediment from streets. Even with these measures implemented, sediment and tracked soil will find their way into the street. *"The Indiana Handbook for Erosion Control in Developing Areas"* contains standards and specifications for several curb inlet protection devices and there are a number of commercial curb inlet protection devices on the market that are designed to capture sediment. However, these practices are not designed to trap large amounts of sediment and require frequent maintenance if they are to remain effective. When selecting a curb inlet protection measure, it is important to select a device that does not block the inlet entirely. Total obstruction of the inlet will cause excessive ponding and in some situations bypass flow that may result in erosion.

- Protect on-site storm sewer drop inlets with silt fence material, straw bales, or equivalent measures. *Refer to drop inlet protection diagram.*

3 Prepare the Site for Construction

Prepare the site for construction and for installation of utilities. Make sure all contractors (*especially the excavating contractor*) are aware of areas to be protected.

Salvage and Stockpile Topsoil or Subsoil

- Remove topsoil (*typically the upper four to six inches of the soil material*) and stockpile.
- Remove subsoil, including any excavated material associated with basement construction, and stockpile separately from the topsoil.
- On small building sites, it may not be feasible to stockpile soil material on each individual lot due to space limitations. In these situations, soil material should be transported to protected areas designated on the overall construction plan or those areas designated by the developer.
- Locate the stockpiles away from any downslope street, driveway, stream, lake, wetland, ditch or drainageway.
- Immediately after stockpiling, temporary seed the stockpiles with annual rye or winter wheat and/or install sediment barriers around the perimeter of the piles.

4 Build Structure(s) and Install Utilities

Construct the home and install the utilities; also install the sewage disposal system and drill water well (*if applicable*); then consider the following:

Install Downspout Extenders

- Although not required, downspout extenders are highly recommended as a means of preventing lot erosion from roof runoff.
- Add the extenders as soon as the gutters and downspouts are installed.
- Be sure the extenders have a stable outlet, such as a paved area, or a well vegetated area. Do not route runoff directly to a street in winter due to the formation of ice. *Refer to temporary downspout extenders diagram.*

5 Maintain Control Practices

Maintain all erosion and sediment control practices until construction is completed and the lot is stabilized.

- Inspect the control practices a minimum of twice a week and after each storm event, making any needed repairs immediately.
- Toward the end of the each work day, sweep or scrape up any soil tracked onto roadway(s). Do not flush areas with water.

6 Revegetate Building Site

Immediately after all outside construction activities are completed, stabilize the lot with sod, seed, and/ or mulch.

Redistribute the Stockpiled Subsoil and Topsoil

- Spread the stockpiled subsoil to rough grade.
- Spread the stockpiled topsoil to a depth of four to six inches over rough-graded areas.
- Fertilize and lime according to soil test results or recommendations of a seed supplier or a professional landscaping contractor.

Seed or Sod Bare Areas

- Contact local seed suppliers or professional landscaping contractors for recommended seeding mixtures and rates.
- Follow recommendations of a professional landscaping contractor for installation of sod.
- Water newly seeded or sodded areas every day or two to keep the soil moist. Less watering is needed once grass is two inches tall.

Mulch Newly Seeded Areas

- Spread straw mulch on newly seeded areas, using one and one-half to two bales of straw per 1,000 square feet.
- On flat or gently sloping land, anchor the mulch by crimping it two to four inches into the soil. On steep slopes, anchor the mulch with netting or tackifiers. An alternative to anchored mulch would be the use of erosion control blankets.

7 Remove Remaining Temporary Control Measures

Once the sod and/or vegetation is well established, remove any remaining temporary erosion and sediment control practices, such as:

- Remove downspout extenders. Or, shorten to outlet on an established vegetated area, allowing for maximum filtration.
- Remove storm sewer inlet protection measures.

APPENDIX D

WORKSHEETS FROM NRCS TR NO. 55: URBAN HYDROLOGY FOR SMALL WATERSHEDS

Worksheet 2: Runoff curve number and runoff

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed

1. Runoff curve number

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN [1/] Table 2-2	CN Figure 2-3	CN Figure 2-4	Area ☐ acres ☐ mi^2 ☐ %	Product of CN x area
				Totals ➡		

[1/] Use only one CN source per line

CN (weighted) = $\frac{\text{total product}}{\text{total area}}$ = ________ = ______ ; **Use CN** ➡ ☐

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr			
Rainfall, P (24-hour)	in			
Runoff, Q .... (Use P and CN with table 2-1, figure 2-1, or equations 2-3 and 2-4)	in			

Worksheet 3: Time of Concentration (T_c) or travel time (T_t)

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed

Check one: ☐ T_c ☐ T_t through subarea

Notes: Space for as many as two segments per flow type can be used for each worksheet.
Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to Tc only)

Segment ID				
1. Surface description (table 3-1)				
2. Manning's roughness coefficient, n (table 3-1)				
3. Flow length, L (total L † 300 ft) .... ft				
4. Two-year 24-hour rainfall, P_2 .... in				
5. Land slope, s .... ft/ft				
6. $T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{\ 0.5}\ s^{0.4}}$ Compute T_t .... hr		+		=

Shallow concentrated flow

Segment ID				
7. Surface description (paved or unpaved)				
8. Flow length, L ....ft				
9. Watercourse slope, s .... ft/ft				
10. Average velocity, V (figure 3-1) .... ft/s				
11. $T_t = \frac{L}{3600\ V}$ Compute T_t .... hr		+		=

Channel flow

Segment ID				
12. Cross sectional flow area, a .... ft^2				
13. Wetted perimeter, p_w .... ft				
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r .... ft				
15 Channel slope, s .... ft/ft				
16. Manning's roughness coefficient, n				
17. $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V ....ft/s				
18. ~~Flow~~ length, L .... ft				
19. $T_t = \frac{L}{3600\ V}$ Compute T_t .... hr		+		=

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... Hr ☐

Worksheet 4: Graphical Peak Discharge method

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed

1. Data

Drainage area .... A_m = _______________ mi^2 (acres/640)

Runoff curve number ....CN = _______________ (From worksheet 2)

Time of concentration .... T_c = _______________ hr (From worksheet 3)

Rainfall distribution .... = ________________ (I, IA, II III)

Pond and swamp areas sprea
throughout watershed .... = _____________ percent of A_m (_________ acres or mi^2 covered)

		Storm #1	Storm #2	Storm #3
2. Frequency	yr			
3. Rainfall, P (24-hour)	in			
4. Initial abstraction, I_a .... (Use CN with table 4-1)	in			
5. Compute I_a / P				
6. Unit peak discharge, q_u .... (Use T_c and I_a / P with exhibit 4– ______)	csm/in			
7. Runoff, Q .... (From worksheet 2) Figure 2-6	in			
8. Pond and swamp adjustment factor, F_p .... (Use percent pond and swamp area with table 4-2. Factor is 1.0 for zero percent pond ans swamp area.)				
9. Peak discharge, q_p	ft^3/s			

(Where $q_p = q_u A_m Q F_p$)

Worksheet 5a: Basic watershed data

Project	Location	By	Date
Check one: ☐ Present ☐ Developed	Frequency (yr)	Checked	Date

Subarea name	Drainage area A_m (mi²)	Time of concen-tration T_c (hr)	Travel time through subarea T_t (hr)	Downstream subarea names	Travel time summation to outlet ΣT_t (hr)	24-hr rain-fall P (in)	Runoff curve number CN	Runoff Q (in)	A_mQ (mi²—in)	Initial abstraction I_a (in)	I_a/P

From worksheet 3 | From worksheet 2 | From table 5-1

Worksheet 5b: Basic watershed data

Project	Location	By	Date
Check one: ☐ Present ☐ Developed	Frequency (yr)	Checked	Date

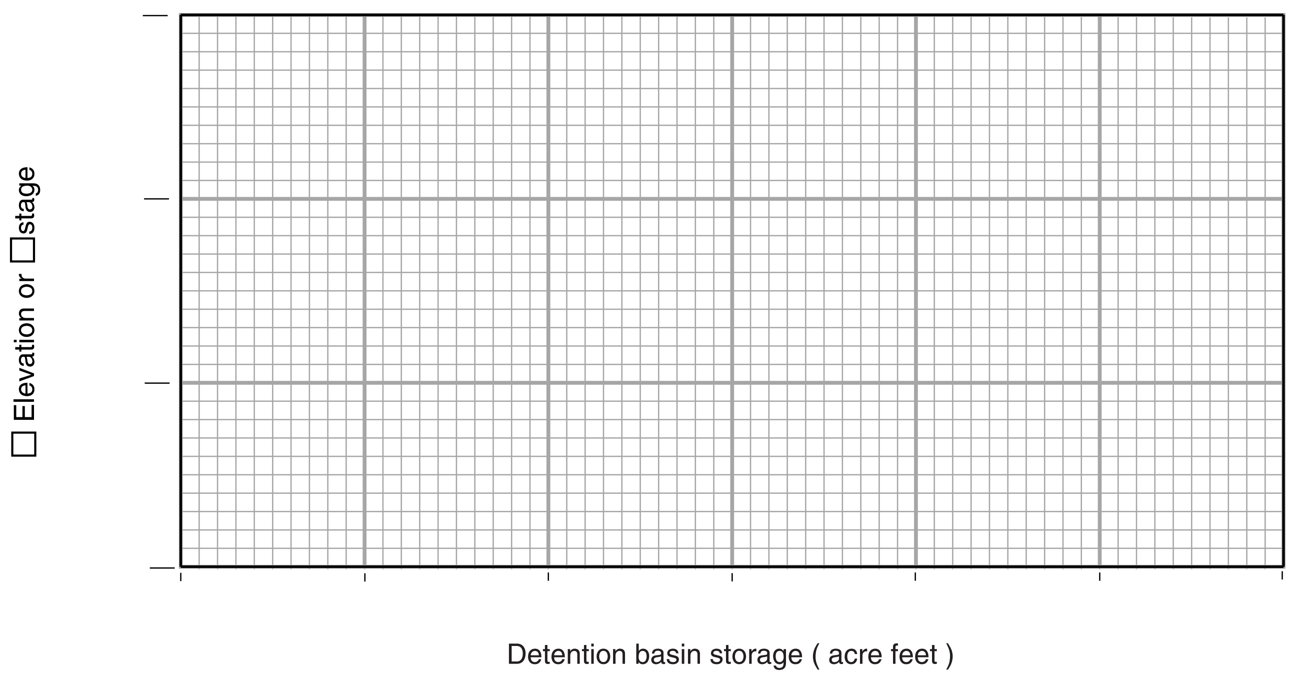
Subarea name	Basic watershed data used 1/				Select and enter hydrograph times in hours from exhibit 5-II 2/											
	Subarea T_c (hr)	ΣT_t to outlet (hr)	I_a/P	A_mQ (mi^2—in)												
					Discharges at selected hydrograph times 3/ (cfs)											
Composite hydrograph at outlet																

1/ Worksheet 5a. Rounded as needed for use with exhibit 5.
2/ Enter rainfall distribution type used.
3/ Hydrograph discharge for selected times is A_mQ multiplied by tabular discharge from appropriate exhibit 5.

Worksheet 6a: Detention basin storage, peak outflow discharge (q_o) known

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed



1. Data:
   Drainage area .... A_m = ________ mi^2
   Rainfall distribution type (I, IA, II, III) = ________

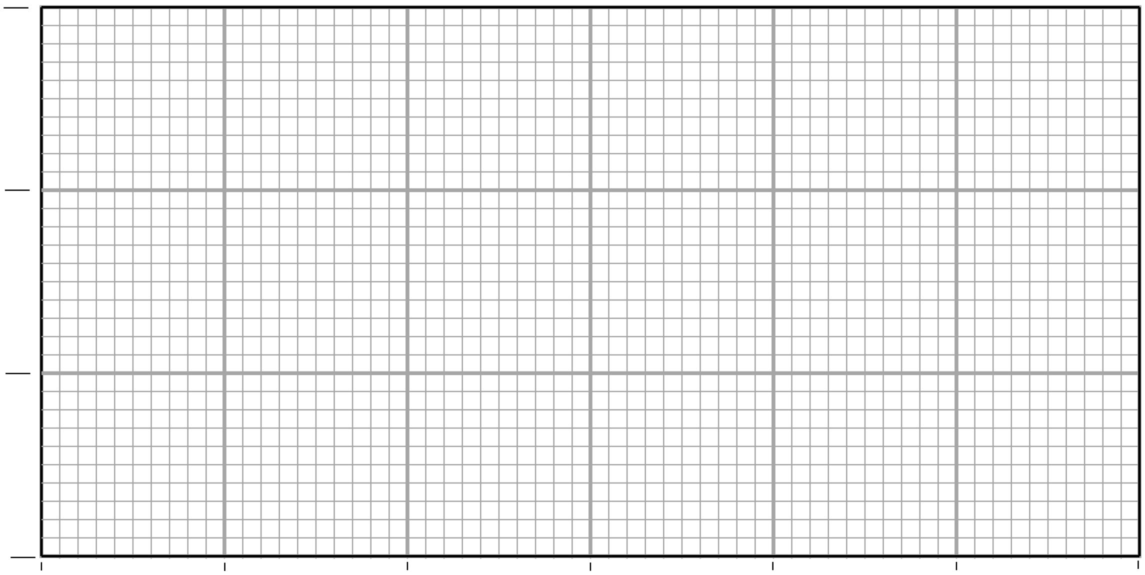
	1st Stage	2nd Stage
2. Frequency .... yr		
3. Peak inflow discharge q_i .... ft^3/s (from worksheet 4 or 5b)		
4. Peak outflow discharge q_u .... ft^3/s [1]		
5. Compute $\frac{q_o}{q_i}$		
6. $\frac{V_s}{V_r}$ .... (Use $\frac{q_o}{q_i}$ with figure 6-1)		
7. Runoff, Q .... in (From worksheet 2)		
8. Runoff volume V_r.................. ac ft ($V_r = QA_m$ 53.33)		
9. Storage volume, V_s .... ac-ft ($V_s = V_r (\frac{V_s}{V_r})$)		
10. Maximum storage E_{max} (from plot)		

[1] 2nd stage q_o includes 1st stage q_o.

Worksheet 6b: Detention basin storage, storage volume (V_s) known

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed



☐ Elevation or ☐ stage

Detention basin storage

1. Data:
   Drainage area .... A_m = ________ mi^2
   Rainfall distribution
   type (I, IA, II, III) = ________

	1st Stage	2nd Stage
2. Frequency .... yr		
3. Storage volume V_s .... ac-ft		
4. Runoff, Q .... in (from worksheet 2)		
5. Runoff volume ..... ac-ft ($V_r = QA_m$ 53.33)		
6. Compute $\frac{V_s}{V_r}$		
7. $\frac{q_o}{q_i}$ .... in (Use $\frac{V_s}{V_r}$ with figure 6-1)		
8. Peak inflow discharge q_i .... in (From worksheet 4 or 5b)		
9. Peak outflow discharge q_o .... ft^3/s ($q_o = q_i (\frac{q_o}{q_i})$)		1/
10. Maximum storage E_{max} (from plot)		

1/ 2nd stage q_o includes 1st stage q_o.

APPENDIX E

BMP CONSTRUCTION INSPECTION CHECKLISTS

Stormwater Pond Construction Inspection Checklist

Project: ______________________________
Location: ______________________________
Site Status: ______________________________

Date: ______________________________

Time: ______________________________

Inspector: ______________________________

CONSTRUCTION SEQUENCE	SATISFACTORY / UNSATISFACTORY	COMMENTS
1. Materials and Equipment		
Pipe and appurtenances on-site prior to construction and dimensions checked		
1. Material (including protective coating, if specified)		
2. Diameter		
3. Dimensions of metal riser or pre-cast concrete outlet structure		
4. Required dimensions between water control structures (orifices, weirs, etc.) are in accordance with approved plans		
5. Barrel stub for prefabricated pipe structures at proper angle for design barrel slope		
6. Number and dimensions of prefabricated anti-seep collars		
7. Watertight connectors and gaskets		
8. Outlet drain valve		
Project benchmark near pond site		
Equipment for temporary de-watering		

CONSTRUCTION SEQUENCE	SATISFACTORY / UNSATISFACTORY	COMMENTS
2. Subgrade Preparation		
Area beneath embankment stripped of all vegetation, topsoil, and organic matter		
3. Pipe Spillway Installation		
Method of installation detailed on plans		
A. Bed preparation		
Installation trench excavated with specified side slopes		
Stable, uniform, dry subgrade of relatively impervious material (If subgrade is wet, contractor shall have defined steps before proceeding with installation)		
Invert at proper elevation and grade		
B. Pipe placement		
Metal / plastic pipe		
1. Watertight connectors and gaskets properly installed		
2. Anti-seep collars properly spaced and having watertight connections to pipe		
3. Backfill placed and tamped by hand under Ahaunches@ of pipe		
4. Remaining backfill placed in max. 8 inch lifts using small power tamping equipment until 2 feet cover over pipe is reached		

CONSTRUCTION SEQUENCE	SATISFACTORY / UNSATISFACTORY	COMMENTS
3. Pipe Spillway Installation		
Concrete pipe		
1. Pipe set on blocks or concrete slab for pouring of low cradle		
2. Pipe installed with rubber gasket joints with no spalling in gasket interface area		
3. Excavation for lower half of anti-seep collar(s) with reinforcing steel set		
4. Entire area where anti-seep collar(s) will come in contact with pipe coated with mastic or other approved waterproof sealant		
5. Low cradle and bottom half of anti-seep collar installed as monolithic pour and of an approved mix		
6. Upper half of anti-seep collar(s) formed with reinforcing steel set		
7. Concrete for collar of an approved mix and vibrated into place (protected from freezing while curing, if necessary)		
8. Forms stripped and collar inspected for honeycomb prior to backfilling. Parge if necessary.		
C. Backfilling		
Fill placed in maximum 8 inch lifts		
Backfill taken minimum 2 feet above top of anti-seep collar elevation before traversing with heavy equipment		

CONSTRUCTION SEQUENCE	SATISFACTORY / UNSATISFACTORY	COMMENTS
4. Riser / Outlet Structure Installation		
Riser located within embankment		
A. Metal riser		
Riser base excavated or formed on stable subgrade to design dimensions		
Set on blocks to design elevations and plumbed		
Reinforcing bars placed at right angles and projecting into sides of riser		
Concrete poured so as to fill inside of riser to invert of barrel		
B. Pre-cast concrete structure		
Dry and stable subgrade		
Riser base set to design elevation		
If more than one section, no spalling in gasket interface area; gasket or approved caulking material placed securely		
Watertight and structurally sound collar or gasket joint where structure connects to pipe spillway		
C. Poured concrete structure		
Footing excavated or formed on stable subgrade, to design dimensions with reinforcing steel set		
Structure formed to design dimensions, with reinforcing steel set as per plan		
Concrete of an approved mix and vibrated into place (protected from freezing while curing, if necessary)		
Forms stripped & inspected for Ahoneycomb@		

CONSTRUCTION SEQUENCE	SATISFACTORY / UNSATISFACTORY	COMMENTS
prior to backfilling; parge if necessary		
5. Embankment Construction		
Fill material		
Compaction		
Embankment		
1. Fill placed in specified lifts and compacted with appropriate equipment		
2. Constructed to design cross-section, side slopes and top width		
3. Constructed to design elevation plus allowance for settlement		
6. Impounded Area Construction		
Excavated / graded to design contours and side slopes		
Inlet pipes have adequate outfall protection		
Forebay(s)		
Pond benches		
7. Earth Emergency Spillway Construction		
Spillway located in cut or structurally stabilized with riprap, gabions, concrete, etc.		
Excavated to proper cross-section, side slopes and bottom width		
Entrance channel, crest, and exit channel constructed to design grades and elevations		

CONSTRUCTION SEQUENCE	SATISFACTORY / UNSATISFACTORY	COMMENTS
8. Outlet Protection		
A. End section		
Securely in place and properly backfilled		
B. Endwall		
Footing excavated or formed on stable subgrade, to design dimensions and reinforcing steel set, if specified		
Endwall formed to design dimensions with reinforcing steel set as per plan		
Concrete of an approved mix and vibrated into place (protected from freezing, if necessary)		
Forms stripped and structure inspected for Ahoneycomb@ prior to backfilling; parge if necessary		
C. Riprap apron / channel		
Apron / channel excavated to design cross-section with proper transition to existing ground		
Filter fabric in place		
Stone sized as per plan and uniformly place at the thickness specified		
9. Vegetative Stabilization		
Approved seed mixture or sod		
Proper surface preparation and required soil amendments		
Excelsior mat or other stabilization, as per plan		

CONSTRUCTION SEQUENCE	SATISFACTORY / UNSATISFACTORY	COMMENTS
10. Miscellaneous		
Drain for ponds having a permanent pool		
Trash rack / anti-vortex device secured to outlet structure		
Trash protection for low flow pipes, orifices, etc.		
Fencing (when required)		
Access road		
Set aside for clean-out maintenance		

Comments:

Actions to be Taken:

Bioretention Construction Inspection Checklist

Project: ______________________________

Location: ______________________________

Site Status: ______________________________

Date: ______________________________

Time: ______________________________

Inspector: ______________________________

CONSTRUCTION SEQUENCE	SATISFACTORY / UNSATISFACTORY	COMMENTS
1. Pre-Construction		
Pre-construction meeting		
Runoff diverted		
Facility area cleared		
If designed as exfilter, soil testing for permeability		
Facility location staked out		
2. Excavation		
Size and location		
Lateral slopes completely level		
If designed as exfilter, ensure that excavation does not compact susoils.		
Longitudinal slopes within design range		

CONSTRUCTION SEQUENCE	SATISFACTORY / UNSATISFACTORY	COMMENTS
3. Structural Components		
Stone diaphragm installed correctly		
Outlets installed correctly		
Underdrain		
Pretreatment devices installed		
Soil bed composition and texture		
4. Vegetation		
Complies with planting specs		
Topsoil adequate in composition and placement		
Adequate erosion control measures in place		
5. Final Inspection		
Dimensions		
Proper stone diaphragm		
Proper outlet		
Soil/ filter bed permeability testing		
Effective stand of vegetation and stabilization		
Construction generated sediments removed		
Contributing watershed stabilized before flow is diverted to the practice		

Comments:

Actions to be Taken:

Sand/Organic Filter System Construction Inspection Checklist

Project: ____________________

Location: ____________________

Site Status: ____________________

Date: ____________________

Time: ____________________

Inspector: ____________________

CONSTRUCTION SEQUENCE	SATISFACTORY / UNSATISFACTORY	COMMENTS
1. Pre-construction		
Pre-construction meeting		
Runoff diverted		
Facility area cleared		
Facility location staked out		
2. Excavation		
Size and location		
Side slopes stable		
Foundation cleared of debris		
If designed as exfilter, excavation does not compact subsoils		
Foundation area compacted		

3. Structural Components		
Dimensions and materials		
Forms adequately sized		
Concrete meets standards		
Prefabricated joints sealed		
Underdrains (size, materials)		
4. Completed Facility Components		
24 hour water filled test		
Contributing area stabilized		
Filter material per specification		
Underdrains installed to grade		
Flow diversion structure properly installed		
Pretreatment devices properly installed		
Level overflow weirs, multiple orifices, distribution slots		
5. Final Inspection		
Dimensions		
Surface completely level		
Structural components		
Proper outlet		
Ensure that site is properly stabilized before flow is directed to the structure.		

Comments:

Actions to be Taken:

Open Channel System Construction Inspection Checklist

Project: ______________________________
Location: ______________________________
Site Status: ______________________________

Date: ______________________________

Time: ______________________________

Inspector: ______________________________

CONSTRUCTION SEQUENCE	SATISFACTORY / UNSATISFACTORY	COMMENTS
1. Pre-Construction		
Runoff diverted		
Area stabilized		
Facility location staked out		
2. Excavation		
Size and location		
Side slope stable		
Soil permeability		
Groundwater / bedrock		
Lateral slopes completely level		
Longitudinal slopes within design range		
3. Check dams		
Dimensions		
Spacing		
Materials		

CONSTRUCTION SEQUENCE	SATISFACTORY / UNSATISFACTORY	COMMENTS
4. Structural Components		
Underdrain installed correctly		
Inflow installed correctly		
Pretreatment devices installed		
5. Vegetation		
Complies with planting specifications		
Topsoil adequate in composition and placement		
Adequate erosion control measures in place		
6. Final inspection		
Dimensions		
Check dams		
Proper outlet		
Effective stand of vegetation and stabilization		

Comments:

Actions to be Taken:

APPENDIX F

BMP OPERATION, MAINTENANCE, AND MANAGEMENT INSPECTION CHECKLISTS

Stormwater Pond Operation, Maintenance, and Management Inspection Checklist

Project: ______________________
Location: ______________________
Site Status: ______________________

Date: ______________________
Time: ______________________

Inspector: ______________________

Maintenance Item	Satisfactory / Unsatisfactory	Comments
1. Embarkment and emergency spillway (Annual, After Major Storms)		
1. Vegetation and ground cover adequate		
2. Embarkment erosion		
3. Animal burrows		
4. Unauthorized planting		
5. Cracking, bulging, or sliding of dam		
a. Upstream face		
b. Downstream face		
c. At or beyond toe		
downstream		
upstream		
d. Emergency spillway		
6.Pond, toe & chimney drains clear and functioning		
7.Seeps/leaks on downstream face		

Maintenance Item	Satisfactory / Unsatisfactory	Comments
8.Slope protection or riprap failure		
9. Vertical/horizontal alignment of top of dam "As-Built"		
10. Emergency spillway clear of obstructions and debris		
11. Other (specify)		
2. Riser and principal spillway (Annual)		
Type: Reinforced concrete ______ Corrugated pipe ______ Masonry ______ 1. Low flow orifice obstructed		
2. Low flow trash rack. a. Debris removal necessary		
b. Corrosion control		
3. Weir trash rack maintenance a. Debris removal necessary		
b. corrosion control		
4. Excessive sediment accumulation insider riser		
5. Concrete/masonry condition riser and barrels a. cracks or displacement		
b. Minor spalling (<1")		
c. Major spalling (rebars exposed)		
d. Joint failures		
e. Water tightness		
6. Metal pipe condition		

Maintenance Item	Satisfactory / Unsatisfactory	Comments
7. Control valve a. Operational/exercised		
b. Chained and locked		
8. Pond drain valve a. Operational/exercised		
b. Chained and locked		
9. Outfall channels functioning		
10. Other (specify)		
3. Permanent Pool (Wet Ponds) (monthly)		
1. Undesirable vegetative growth		
2. Floating or floatable debris removal required		
3. Visible pollution		
4. Shoreline problem		
5. Other (specify)		
4. Sediment Forebays		
1.Sedimentation noted		
2. Sediment cleanout when depth < 50% design depth		
5. Dry Pond Areas		
1. Vegetation adequate		
2. Undesirable vegetative growth		
3. Undesirable woody vegetation		
4. Low flow channels clear of obstructions		
5.Standing water or wet spots		

Maintenance Item	**Satisfactory / Unsatisfactory**	**Comments**
6. Sediment and / or trash accumulation		
7. Other (specify)		
6. Condition of Outfall into Ponds (Annual , After Major Storms)		
1. Reprap failures		
2. Slope erosion		
3. Storm drain pipes		
4.Endwalls / Headwalls		
5. Other (specify)		
7. Other (Monthly)		
1. Encroachment on pond or easement area		
2. Complaints from residents		
3.Aesthetics a. Grass growing required		
b. Graffiti removal needed		
c. Other (specify)		
4. Any public hazards (specify)		
8. Constructed Wetland area (Annual)		
1. Vegetation healthy and growing		
2.Evidence of invasive species		
3. Excessive sedimentation in Wetland area		

Comments:

Actions to be Taken:

Infiltration Trench Operation, Maintenance, and Management Inspection Checklist

Project: ______________________________

Location: ______________________________

Site Status: ______________________________

Date: ______________________________

Time: ______________________________

Inspector: ______________________________

MAINTENANCE ITEM	SATISFACTORY / UNSATISFACTORY	COMMENTS
1. Debris Cleanout (Monthly)		
Trench surface clear of debris		
Inflow pipes clear of debris		
Overflow spillway clear of debris		
Inlet area clear of debris		
2. Sediment Traps or Forebays (Annual)		
Obviously trapping sediment		
Greater than 50% of storage volume remaining		
3. Dewatering (Monthly)		
Trench dewaters between storms		
4. Sediment Cleanout of Trench (Annual)		
No evidence of sedimentation in trench		
Sediment accumulation doesn=t yet		

MAINTENANCE ITEM	SATISFACTORY / UNSATISFACTORY	COMMENTS
require cleanout		
5. Inlets (Annual)		
Good condition		
No evidence of erosion		
6. Outlet/Overflow Spillway (Annual)		
Good condition, no need for repair		
No evidence of erosion		
7. Aggregate Repairs (Annual)		
Surface of aggregate clean		
Top layer of stone does not need replacement		
Trench does not need rehabilitation		

Comments:

Actions to be Taken:

Infiltration Basin Operation, Maintenance, Management and Inspection Checklist

Project: ______________________________
Location: ______________________________
Site Status: ______________________________

Date: ______________________________

Time: ______________________________

Inspector: ______________________________

MAINTENANCE ITEM	SATISFACTORY / UNSATISFACTORY	COMMENTS
1. Debris Cleanout (Monthly)		
Basin Bottom Clear of Debris		
Inlet Clear of Debris		
Outlet Clear of Debris		
Emergency Spillway Clear of Debris		
2. Sediment Traps or Forebays (Annual)		
Obviously trapping sediment		
Greater than 50% of storage volume remaining		
3. Vegetation (monthly)		
Mowing done when needed		
No evidence of erosion		
Fertilized per specifications		
4. Dewatering (Monthly)		
Basin dewaters between storms		

MAINTENANCE ITEM	SATISFACTORY / UNSATISFACTORY	COMMENTS
5. Sediment Cleanout of Basin (Annual)		
No evidence of sedimentation		
Sediment accumulation does not yet require cleanout		
6. Inlets (Annual)		
Good condition		
No evidence of erosion		
7. Outlet/Overflow Spillway (Annual, After Major Storms)		
Good condition, no need for repair		
No evidence of erosion		
8. Structural Repairs (Annual, After Major Storms)		
Embankment in good repair		
Side slopes are stable		
No evidence of erosion		
9. Fences/Access Repairs (Annual)		
Fences in good condition		
No damage which would allow undesirable entry		
Lock and gate function adequate		
Access point in good condition		

Comments:

Actions to be Taken:

Bioretention Operation, Maintenance, and Management Inspection Checklist

Project: ______________________________
Location: ______________________________
Site Status: ______________________________

Date: ______________________________

Time: ______________________________

Inspector: ______________________________

MAINTENANCE ITEM	SATISFACTORY / UNSATISFACTORY	COMMENTS
1. Debris Cleanout (Monthly)		
Bioretention and contributing areas clean of debris		
No dumping of yard wastes into practice		
Litter (branches, etc.) have been removed		
2. Vegetation (Monthly)		
Plant height not less than design water depth		
Fertilized per specifications		
Plant composition according to approved plans		
No placement of inappropriate plants		
Grass height not greater than 6 inches		

MAINTENANCE ITEM	**SATISFACTORY / UNSATISFACTORY**	**COMMENTS**
No evidence of erosion		

Maintenance Item	**Satisfactory / Unsatisfactory**	**Comments**
3. Check Dams/Energy Dissipaters/Sumps (Annual, After Major Storms)		
No evidence of sediment buildup		
Sumps should not be more than 50% full of sediment		
No evidence of erosion at downstream toe of drop structure		
4. Dewatering (Monthly)		
Dewaters between storms		
No evidence of standing water		
5. Sediment Deposition (Annual)		
Swale clean of sediments		
Sediments should not be > 20% of swale design depth		
6. Outlet/Overflow Spillway (Annual, After Major Storms)		
Good condition, no need for repair		
No evidence of erosion		
No evidence of any blockages		
7. Integrity of Filter Bed (Annual)		
Filter bed has not been blocked or filled inappropriately		

Comments:

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Actions to be Taken:

Sand/Organic Filter Operation, Maintenance, and Management Inspection Checklist

Project: ____________________

Location: ____________________

Site Status: ____________________

Date: ____________________

Time: ____________________

Inspector: ____________________

MAINTENANCE ITEM	SATISFACTORY / UNSATISFACTORY	COMMENTS
1. Debris Cleanout (Monthly)		
Contributing areas clean of debris		
Filtration facility clean of debris		
Inlet and outlets clear of debris		
2. Oil and Grease (Monthly)		
No evidence of filter surface clogging		
Activities in drainage area minimize oil and grease entry		
3. Vegetation (Monthly)		
Contributing drainage area stabilized		
No evidence of erosion		
Area mowed and clipping removed		

MAINTENANCE ITEM	SATISFACTORY / UNSATISFACTORY	COMMENTS
4. Water Retention Where Required (Monthly)		
Water holding chambers at normal pool		
No evidence of leakage		
5. Sediment Deposition (Annual)		
Filter chamber free of sediments		
Sedimentation chamber not more than half full of sediments		
6. Structural Components (Annual)		
No evidence of structural deterioration		
Any grates are in good condition		
No evidence of spalling or cracking of structural parts		
7. Outlet/Overflow Spillway (Annual)		
Good condition, no need for repairs		
No evidence of erosion (if draining into a natural channel)		
8. Overall Function of Facility (Annual)		
Evidence of flow bypassing facility		
No noticeable odors outside of facility		

Comments:

Actions to be Taken:

Open Channel Operation, Maintenance, and Management Inspection Checklist

Project: ______________________________
Location: ______________________________
Site Status: ______________________________

Date: ______________________________

Time: ______________________________

Inspector: ______________________________

MAINTENANCE ITEM	SATISFACTORY / UNSATISFACTORY	COMMENTS
1. Debris Cleanout (Monthly)		
Contributing areas clean of debris		
2. Check Dams or Energy Dissipators (Annual, After Major Storms)		
No evidence of flow going around structures		
No evidence of erosion at downstream toe		
Soil permeability		
Groundwater / bedrock		
3. Vegetation (Monthly)		
Mowing done when needed		
Minimum mowing depth not exceeded		
No evidence of erosion		
Fertilized per specification		

MAINTENANCE ITEM	SATISFACTORY / UNSATISFACTORY	COMMENTS
4. Dewatering (Monthly)		
Dewaters between storms		
5. Sediment deposition (Annual)		
Clean of sediment		
6. Outlet/Overflow Spillway (Annual)		
Good condition, no need for repairs		
No evidence of erosion		

Comments:

Actions to be Taken:

APPENDIX G

POST CONSTRUCTION STRUCTURAL BMP FACTSHEETS

BMP FACTSHEET
DETENTION PONDS

DETENTION PONDS

Source: Symbiont

Water Quantity Benefits (low, medium, high)	
Rate Reduction	**High**
Volume Reduction	**Low**
Water Quality Benefits (% Reduction)	
Total Suspended Solids (TSS)	**61**
Total Phosphorus (P)	**19**
Total Nitrogen (N)	**31**
Metals	**26-54**
Oils and Grease	**NA**
Bacteria	**NA**
Other Considerations (low, medium, high or other)	
Area Typically Served (acres)	**1-2**
% of Area Needed for BMP	**0.5-1**
Capital Costs	**Medium**
O& M Costs	**High**
Maintenance	**High**
Training	**Medium**
Effective Life (years)	**50-100**

DESCRIPTION

Detention ponds (a.k.a. dry ponds, extended detention basins, detention ponds, extended detention ponds) are basins whose outlets have been designed to detain stormwater runoff for some minimum time (e.g., 24 hours) to allow particles and associated pollutants to settle. Unlike wet ponds, these facilities do not have a large permanent pool of water. However, they are often designed with small pools at the inlet and outlet of the basin. They can also be used to provide flood control by including additional flood detention storage.

APPLICABILITY

Dry detention ponds have traditionally been one of the most widely used stormwater best management practices. In some instances, these ponds may be the most appropriate best management practice. However, they should not be used as a one size fits all solution. If pollutant removal efficiency is an important consideration then dry detention ponds may not be the most appropriate choice. Dry detention ponds require a large amount of space to build them. In many instances, smaller-sized best management practices are more appropriate alternatives.

Regional Applicability

Dry detention ponds can be applied in all regions of the United States. Some minor design modifications might be needed, however, in cold or arid climates or in regions with karst (i.e. limestone) topography.

Ultra-Urban Areas

Ultra-urban areas are densely developed urban areas in which little pervious surface is present. It is difficult to use dry detention ponds in the ultra-urban environment because of the land area each pond consumes.

Stormwater Hot Spots

Stormwater hot spots are areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in stormwater. Dry detention ponds can accept runoff from stormwater hot spots, but they need significant separation from ground water if they will be used for this purpose.

Stormwater Retrofit

A stormwater retrofit is a stormwater management practice (usually structural) put into place after development has occurred to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. Dry detention ponds are useful stormwater retrofits, and they have two primary applications as a retrofit design. In many communities in the past, detention basins have been designed for flood control. It is possible to modify these facilities to incorporate features that encourage water quality control and/or channel protection. It is also possible to construct new dry ponds in open areas of a watershed to capture existing drainage.

Cold Water (Trout) Streams

A study in Prince George's County, Maryland, found that stormwater management practices can increase stream temperatures (Galli, 1990). Overall, dry detention ponds increased temperature by about 5°F. In cold water streams, dry ponds should be designed to detain stormwater for a relatively short time (i.e., less than 12 hours) to minimize the amount of warming that occurs in the practice. If the temperature of the water is a factor, then alternative best management practices may be more appropriate.

ADVANTAGES/LIMITATIONS

Although dry detention ponds are widely applicable, they have some limitations that might make other stormwater management options preferable:

Dry detention ponds have only moderate pollutant removal when compared to other structural stormwater practices, and they are ineffective at removing soluble pollutants (See Effectiveness). Dry extended detention ponds may become a nuisance due to mosquito breeding if improperly maintained or if shallow pools of water form for more than 7 days. Although wet ponds can increase property values, dry ponds can actually detract from the value of a home (see Cost Considerations).

Dry detention ponds on their own only provide peak flow reduction and do little to control overall runoff volume, which could result in adverse downstream impacts.

DESIGN & SIZING

Siting Considerations

Designers need to ensure that the dry detention pond is feasible at the site in question. This section provides basic guidelines for siting dry detention ponds.

<u>Drainage Area</u>
In general, dry detention ponds should be used on sites with a minimum area of 10 acres. On smaller sites, it can be challenging to provide channel or water quality control because the orifice diameter at the outlet needed to control relatively small storms becomes very small and thus prone to clogging. Low impact development techniques and on-lot treatment controls are recommended for smaller sites.

<u>Slope</u>

Dry detention ponds can be used on sites with slopes up to about 15 percent. The local slope needs to be relatively flat, however, to maintain reasonably flat side slopes in the practice. There is no minimum slope requirement, but there does need to be enough elevation drop from the pond inlet to the pond outlet to ensure that flow can move through the system.

<u>Soils / Topography</u>

Dry detention ponds can be used with almost all soils and geology, with minor design adjustments for regions of karst topography or in rapidly percolating soils such as sand. In these areas, extended detention ponds should be designed with an impermeable liner to prevent ground water contamination or sinkhole formation.

<u>Ground Water</u>

Except for the case of hot spot runoff, the only consideration regarding ground water is that the base of the extended detention facility should not intersect the ground water table. A permanently wet bottom may become a mosquito breeding ground. Research in Southwest Florida (Santana et al., 1994) demonstrated that intermittently flooded systems, such as dry extended detention ponds, produced more mosquitoes than other pond systems, particularly when the facilities remained wet for more than 3 days following heavy rainfall.

Design Considerations
Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. Some features, however, should be incorporated into most dry extended detention pond designs. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

<u>Pretreatment</u>

Pretreatment incorporates design features that help to settle out coarse sediment particles. By removing these particles from runoff before they reach the large permanent pool, the maintenance burden of the pond is reduced. In ponds, pretreatment is achieved with a sediment forebay, which is a small pool (typically about 10 percent of the volume of water to be treated for pollutant removal).

Treatment

Treatment design features help enhance the ability of a stormwater management practice to remove pollutants. Designing dry ponds with a high length-to-width ratio (i.e., at least 1.5:1) and incorporating other design features to maximize the flow path effectively increases the detention time in the system by eliminating the potential of flow to short-circuit the pond. Designing ponds with relatively flat side slopes can also help to lengthen the effective flow path. Finally, the pond should be sized to detain the volume of runoff to be treated for between 12 and 48 hours.

Conveyance

Conveyance of stormwater runoff into and through the dry pond is a critical component. Stormwater should be conveyed to and from dry ponds safely in a manner that minimizes erosion potential. The outfall of pond systems should always be stabilized to prevent scour. To convey low flows through the system, designers should provide a pilot channel. A pilot channel is a surface channel that should be used to convey low flows through the pond. In addition, an emergency spillway should be provided to safely convey large flood events. To help mitigate the warming of water at the outlet channel, designers should provide shade around the channel at the pond outlet.

MAINTENANCE

In addition to incorporating features into the pond design to minimize maintenance, some regular maintenance and inspection practices are needed. Table 1 outlines some of these practices.

Table 1. Typical maintenance activities for dry ponds (Source: Modified from WMI, 1997)

Activity	**Schedule**
Note erosion of pond banks or bottom	Semiannual inspection
Inspect for damage to the embankment Monitor for sediment accumulation in the facility and forebay Examine to ensure that inlet and outlet devices are free of debris and operational	Annual inspection
Repair undercut or eroded areas Mow side slopes Manage pesticide and nutrients Remove litter and debris	Standard maintenance
Seed or sod to restore dead or damaged ground cover	Annual maintenance (as needed)
Remove sediment from the forebay	5- to 7-year maintenance
Monitor sediment accumulations, and remove sediment when the pond volume has been reduced by 25 percent	25- to 50-year maintenance

Regular maintenance activities are needed to maintain the function of stormwater practices. In addition, some design features can be incorporated to ease the maintenance burden of each practice. In dry detention ponds, a "micropool" at the outlet can prevent resuspension of sediment and outlet clogging. A good design includes maintenance access to the forebay and micropool.

Another design feature that can reduce maintenance needs is a non-clogging outlet. Typical examples include a reverse-slope pipe or a weir outlet with a trash rack. A reverse slope pipe draws from below the permanent pool extending in a reverse angle up to the riser and determines the water elevation of the micropool. Because these outlets draw water from below the level of the permanent pool, they are less likely to be clogged by floating debris.

Landscaping
Designers should maintain a vegetated buffer around the pond and should select plants within the extended detention zone (i.e., the portion of the pond up to the elevation where stormwater is detained) that can withstand both wet and dry periods. The side slopes of dry ponds should be relatively flat to reduce safety risks.

Regional Variations

Arid or Semi-Arid Climates

In arid and semi-arid regions, some modifications might be needed to conserve scarce water resources. Any landscaping plans should prescribe drought-tolerant vegetation wherever possible. In addition, the wet forebay can be replaced with an alternative dry pretreatment, such as a detention cell. In regions with a distinct wet and dry season, as in many arid regions, regional detention ponds can possibly be used as a recreation area such as a ball field during the dry season.

Cold Climates

In cold climates, some additional design features can help to treat the spring snowmelt. One such modification is to increase the volume available for detention to help treat this relatively large runoff event. In some cases, dry facilities may be an option as a snow storage facility to promote some treatment of plowed snow. If a pond is used to treat road runoff or is used for snow storage, landscaping should incorporate salt-tolerant species. Finally, sediment might need to be removed from the forebay more frequently than in warmer climates (see Maintenance Considerations for guidelines) to account for sediment deposited as a result of road sanding.

EFFECTIVENESS

Structural management practices can be used to achieve four broad resource protection goals: flood control, channel protection, ground water recharge, and pollutant removal. Dry detention basins can provide flood control and channel protection, as well as some pollutant removal.

Flood Control
One objective of stormwater management practices can be to reduce the flood hazard associated with large storm events by reducing the peak flow associated with these storms. Dry extended detention basins can easily be designed for flood control, and this is actually the primary purpose of most detention ponds.

Channel Protection

DETENTION PONDS

One result of urbanization is the geomorphic changes that occur in response to modified hydrology. Traditionally, dry detention basins have provided control of the 2-year storm (i.e., the storm that occurs, on average, once every 2 years) for channel protection. It appears that this control has been relatively ineffective, and research suggests that control of a smaller storm might be more appropriate (MacRae, 1996). Slightly modifying the design of dry detention basins to reduce the flow of smaller storm events might make them effective tools in reducing downstream erosion.

Pollutant Removal

Dry detention basins provide moderate pollutant removal, provided that the design features described in the Siting and Design Considerations section are incorporated. Although they can be effective at removing some pollutants through settling, they are less effective at removing soluble pollutants because of the absence of a permanent pool. There is considerable variability in the effectiveness of ponds, and it is believed that properly designing and maintaining ponds may help to improve their performance. The siting and design criteria presented in this sheet reflect the best current information and experience to improve the performance of wet ponds. A joint project of the American Society of Civil Engineers (ASCE) and the USEPA Office of Water might help to isolate specific design features that can improve performance. The National Stormwater Best Management Practice (BMP) database is a compilation of stormwater practices that includes both design information and performance data for various practices. As the database expands, inferences about the extent to which specific design criteria influence pollutant removal may be made.

COST

The construction costs associated with dry detention ponds range considerably. Dry detention ponds are generally less expensive on a given site, because they are usually smaller than a wet pond design.
Ponds do not consume a large area compared to the total area treated (typically 2 to 3 percent of the contributing drainage area). It is important to note, however, that each pond is generally large. Other practices, such as filters or swales, may be "squeezed in" on relatively unusable land, but ponds need a relatively large continuous area.
For ponds, the annual cost of routine maintenance is typically estimated at about 3 to 5 percent of the construction cost. Alternatively, a community can estimate the cost of the maintenance activities outlined in the maintenance section. Finally, ponds are long-lived facilities (typically longer than 20 years). Thus, the initial investment into pond systems can be spread over a relatively long time period.
Another economic concern associated with dry ponds is that they might detract slightly from the value of adjacent properties.

REFERENCES

This fact sheet is copied from the United States Environmental Protection Agency, Menu of BMPs – Post Construction (**http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm**).

BMP FACTSHEET
DETENTION TANKS

DETENTION TANKS

Source: StormTrap

Water Quantity Benefits (low, medium, high)	
Rate Reduction	**High**
Volume Reduction	**Low**

Water Quality Benefits (% Reduction)	
Total Suspended Solids (TSS)	**60-80**
Total Phosphorus (P)	**20-40**
Total Nitrogen (N)	**NA**
Metals	**NA**
Oils and Grease	**NA**
Bacteria	**NA**

Other Considerations (low, medium, high or other)	
Area Typically Served (acres)	**1-2**
% of Area Needed for BMP	**0.5-1**
Capital Costs	**High**
O& M Costs	**High**
Maintenance	**High**
Training	**Medium**
Effective Life (years)	**50-100**

DESCRIPTION

Detention tanks and vaults are aboveground or underground structures used to attenuate peak stormwater flows. They are usually constructed out of either concrete or corrugated metal pipe (CMP) and must consider the potential loading from vehicles on the vault or pipe. Pretreatment structures can be used at the inlet to treat stormwater runoff and remove trash and debris. In addition, flow splitters can be used to direct only a portion of the stormwater runoff to an underdrain detention.

APPLICABILITY

Due to the costs associated with underground detention systems for construction and maintenance, these systems are primarily used when space is limited and there are no other practical alternatives. In the ultra-urban environment, costs for developable land may be high enough that these systems become a feasible alternative. Relatively expensive to construct, concrete vaults are used primarily to control small flows in areas where system replacement costs are high. Less expensive, CMP systems are typically used to control significant volumes of runoff in parking lots, adjacent to rights-of-way, and in medians, where they can be replaced or maintained if necessary.

In the ultra-urban environment, underground detention tanks have been used to decrease flows in combined sewer systems. The stormwater is stored in the tank and then can be released by a remotely controlled valve to the wastewater treatment plant after the peak flows have passed through the plant.

DETENTION TANKS

ADVANTAGES/LIMITATIONS

Detention tanks can be placed underground or aboveground and are particularly useful under parking lots or other sites were aboveground space isn't available. Traffic load can also be supported by most commercially available units.

In-line storage does have some significant limitations. In-line storage practices normally only control flow, and thus are not able to improve the water quality of stormwater runoff. If improperly designed, these practices may cause upstream flooding.

DESIGN & SIZING

The CMP systems used for large storage volumes are usually a series of pipes interconnected by a junction box or main pipe with an outfall structure. There should be a sufficient number of access holes and access points in the system to efficiently inspect and maintain both the outfall structure and the storage area. Whenever possible, the system should be located in an area where maintenance and potential repairs can be conducted with minimal disturbance to surrounding uses. Some design information on CMP systems is available in Design and Construction of Urban Stormwater Management Systems (ASCE, 1992).

Water quality controls, such as water quality inlets and sand filters, are often used to pretreat the stormwater before it enters the system. This is done to remove sediment and pollutants, which might clog the system. CMP systems can work in conjunction with infiltration to provide additional stormwater treatment.

When infiltration is used, perforations may be added to the pipe to allow the pipe to store the water until it can be exfiltrated into the soils below the pipe. In critical areas, such as under roads and parking lots, pipe joints may require gaskets and water-tight seals to protect the integrity of the pipe. Most systems have pipes or vaults inverts that are 1.8 to 3 m (6 to 10 ft) underground. Therefore, it may be difficult to obtain an adequate outfall for the system.

Another type of underground detention is the retrofitting of overcapacity storm drain pipes with baffles. The baffles cause the water to be stored in the pipes and to be released to the outfall at a slower rate (ASCE, 1992).

MAINTENANCE

The cost and maintenance of these systems are major considerations. The systems must be designed so that they can have easy access for inspection and maintenance. Maintenance is usually conducted by periodically pumping out sediments and debris. In areas of high sediment flows, pretreatment is required to minimize the inflow of particulates so that the need to clean the system is reduced. An analysis of other management measures in the watershed is required to ensure that peak release rates are coordinated so that peak flows are reduced to predevelopment rates.

With the facilities located underground, inspection and maintenance are important issues because of the relatively high costs. In the ultra-urban environment, the facilities may require location under structures, such as buildings, parking lots, and roadways. Frequent maintenance is required to remove sediment and debris and to ensure that the outlet structure is functioning properly. Large-scale removal of accumulated sediment in the system may be difficult due to limited access. In addition, underground systems will be considered confined spaces that require additional safety requirements for inspection and maintenance.

EFFECTIVENESS

Underground detention structures are effective measures for stormwater runoff quantity control; however, these facilities do not provide significant water quality control or primary stormwater treatment, without extensive modifications. Consequently, they are more frequently used to attenuate and store peak flows. In addition to providing insignificant stormwater treatment without modifications, receiving waters can be very sensitive to releases of the stored volume from these underground detention systems.

Preliminary results of water quality monitoring of modified underground detention structures have demonstrated a total suspended solids (TSS) removal rate of between 60 to 80 percent; a total phosphorous (TP) reduction of between 20 and 40 percent; and a total lead reduction of between 40 and 70 percent. This facility, however, required weekly maintenance and cleaning out of the structure to maintain this efficiency (Northern Virginia District Planning Commission, 1992). In reality, few detention tanks and vaults receive weekly maintenance.

COST

Due to the high costs associated with concrete structure construction, the use of vaults is limited to small drainage areas. A preliminary cost estimate for the more expensive concrete vaults can be provided by the following equation (Wiegand et al., 1986):

where:

$$C = 38.1 \, (V / 0.02832)^{0.6816}$$

C = construction cost estimate (1995 dollars) and
V = volume of storage (cubic meters) for the maximum design event frequency.

Corrugated metal pipes or plastic pipe have been used extensively in urban areas and are significantly less expensive than vaults for storing large amounts of water. All three systems have long life cycles.

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BMP FACTSHEET
WET RETENTION PONDS

WET RETENTION PONDS

Source: Oregon State University Extension Service, Marion County

Water Quantity Benefits (low, medium, high)	
Rate Reduction	**High**
Volume Reduction	**Low**
Water Quality Benefits (% Reduction)	
Total Suspended Solids (TSS)	**67**
Total Phosphorus (P)	**48**
Total Nitrogen (N)	**31**
Metals	**25**
Oil and Grease	**NA**
Bacteria	**65**
Other Considerations (low, medium, high or other)	
Area Typically Served (acres)	**2 (min)**
% of Area Needed for BMP	**10-20**
Capital Costs	**Medium**
O& M Costs	**Low**
Maintenance	**Low**
Training	**Low**
Effective Life (years)	**20-50**

DESCRIPTION

Wet ponds (a.k.a. storm water ponds, retention ponds, wet extended detention ponds) are constructed basins that have a permanent pool of water throughout the year (or at least throughout the wet season). Ponds treat incoming storm water runoff by settling and algal uptake. The primary removal mechanism is settling as storm water runoff resides in this pool, and pollutant uptake, particularly of nutrients, also occurs through biological activity in the pond. Wet ponds are among the most cost-effective and widely used storm water practices. While there are several different versions of the wet pond design, the most common modification is the extended detention wet pond, where storage is provided above the permanent pool in order to detain storm water runoff in order to provide settling.

APPLICABILITY

Wet ponds are widely applicable storm water management practices. Although they have limited applicability in highly urbanized settings and in arid climates, they have few other restrictions.

Regional Applicability

Wet extended detention ponds can be applied in most regions of the United States, with the exception of arid climates. In arid regions, it is difficult to justify the supplemental water needed to maintain a permanent pool because of the scarcity of water. Even in semi-arid Austin, Texas, one study found that 2.6 acre-feet per year of supplemental water was needed to maintain a permanent pool of only 0.29 acre-feet (Saunders and Gilroy, 1997). Other modifications and design variations are needed in semi-arid and cold climates, and karst (i.e., limestone) topography.

Ultra-Urban Areas

Ultra-urban areas are densely developed urban areas in which little pervious surface exists. It is difficult to use wet ponds in the ultra-urban environment because of the land area each pond consumes. They can, however, be used in an ultra-urban environment if a relatively large area is available downstream of the site.

Storm Water Hot Spots

Storm water hot spots are areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in storm water. A typical example is a gas station. Wet ponds can accept runoff from storm water hot spots, but need significant separation from ground water if they will be used for this purpose.

Storm Water Retrofit

A storm water retrofit is a storm water management practice (usually structural) put into place after development has occurred, to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. Wet ponds are very useful storm water retrofits and have two primary applications as a retrofit design. In many communities, detention ponds have been designed for flood control in the past. It is possible to modify these facilities to develop a permanent wet pool to provide water quality control (see Treatment under Design Considerations), and modify the outlet structure to provide channel protection. Alternatively, wet ponds may be designed in-stream, or in open areas as a part of a retrofit study.

Cold Water (Trout) Streams

Wet ponds pose a risk to cold water systems because of their potential for stream warming. When water remains in the permanent pool, it is heated by the sun. A study in Prince George's County, Maryland, found that storm water wet ponds heat storm water by about 9°F from the inlet to the outlet (Galli, 1990).

ADVANTAGES/LIMITATIONS

Wet ponds are cost effective and very commonly used in storm water management which may make the approval process easier.

Limitations of wet ponds include:

- If improperly located, wet pond construction may cause loss of wetlands or forest.
- Although wet ponds consume a small amount of space relative to their drainage areas, they are often inappropriate in dense urban areas because each pond is generally quite large.
- Their use is restricted in arid and semi-arid regions due to the need to supplement the permanent pool.
- In cold water streams, wet ponds are not a feasible option due to the potential for stream warming.
- Wet ponds may pose safety hazards.

DESIGN AND SITING

Siting Considerations

In addition to the restrictions and modifications to adapting wet ponds to different regions and land uses, designers need to ensure that this management practice is feasible at the site in question. The following section provides basic guidelines for siting wet ponds.

Drainage Area

Wet ponds need sufficient drainage area to maintain the permanent pool. In humid regions, this is typically about 25 acres, but a greater area may be needed in regions with less rainfall.

Slope

Wet ponds can be used on sites with an upstream slope up to about 15 percent. The local slope should be relatively shallow, however. Although there is no minimum slope requirement, there does need to be enough elevation drop from the pond inlet to the pond outlet to ensure that water can flow through the system.

Soils / Topography

Wet ponds can be used in almost all soils and geology, with minor design adjustments for regions of karst topography (see Design Considerations).

Ground Water

Unless they receive hot spot runoff, ponds can often intersect the ground water table. However, some research suggests that pollutant removal is reduced when ground water contributes substantially to the pool volume (Schueler, 1997b).

Design Considerations

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. There are some features, however, that should be incorporated into most wet pond designs. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

Pretreatment

Pretreatment incorporates design features that help to settle out coarse sediment particles. By removing these particles from runoff before they reach the large permanent pool, the maintenance burden of the pond is reduced. In ponds, pretreatment is achieved with a sediment forebay. A sediment forebay is a small pool (typically about 10 percent of the volume of the permanent pool). Coarse particles remain trapped in the forebay, and maintenance is performed on this smaller pool, eliminating the need to dredge the entire pond.

Treatment

Treatment design features help enhance the ability of a storm water management practice to remove pollutants. The purpose of most of these features is to increase the amount of time that storm water remains in the pond.

One technique of increasing the pollutant removal of a pond is to increase the volume of the permanent pool. Typically, ponds are sized to be equal to the water quality volume (i.e., the volume of water treated for pollutant removal). Designers may consider using a larger volume to meet specific watershed objectives, such as phosphorous removal in a lake system. Regardless of the pool size, designers need to conduct a water balance analysis to ensure that sufficient inflow is available to maintain the permanent pool.

Other design features do not increase the volume of a pond, but can increase the amount of time storm water remains in the practice and eliminate short-circuiting. Ponds should always be designed with a length-to-width ratio of at least 1.5:1. In addition, the design should incorporate features to lengthen the flow path through the pond, such as underwater berms designed to create a longer route through the pond. Combining these two measures helps ensure that the entire pond volume is used to treat storm water. Another feature that can improve treatment is to use multiple ponds in series as part of a "treatment train" approach to pollutant removal. This redundant treatment can also help slow the rate of flow through the system.

Conveyance

Storm water should be conveyed to and from all storm water management practices safely and to minimize erosion potential. The outfall of pond systems should always be stabilized to prevent scour. In addition, an emergency spillway should be provided to safely convey large flood events. To help mitigate warming at the outlet channel, designers should provide shade around the channel at the pond outlet.

Maintenance Reduction

In addition to regular maintenance activities needed to maintain the function of storm water practices, some design features can be incorporated to ease the maintenance burden of each practice. In wet ponds, maintenance reduction features include techniques to reduce the amount of maintenance needed, as well as techniques to make regular maintenance activities easier.

One potential maintenance concern in wet ponds is clogging of the outlet. Ponds should be designed with a non-clogging outlet such as a reverse-slope pipe, or a weir outlet with a trash rack. A reverse-slope pipe draws from below the permanent pool extending in a reverse angle up to the riser and establishes the water elevation of the permanent pool. Because these outlets draw water from below the level of the permanent pool, they are less likely to be clogged by floating debris. Another general rule is that no orifice should be less than 3 inches in diameter. (Smaller orifices are more susceptible to clogging).

Design features are also incorporated to ease maintenance of both the forebay and the main pool of ponds. Ponds should be designed with a maintenance access to the forebay to ease this relatively routine (5–7 year) maintenance activity. In addition, ponds should generally have a pond drain to draw down the pond for the more infrequent dredging of the main cell of the pond.

Landscaping

Landscaping of wet ponds can make them an asset to a community and can also enhance the pollutant removal of the practice. A vegetated buffer should be preserved around the pond to protect the banks from erosion and provide some pollutant removal before runoff enters the pond by overland flow. In addition, ponds should incorporate an aquatic bench (i.e., a shallow shelf with wetland plants) around the edge of the pond. This feature may provide some pollutant uptake, and it also helps to stabilize the soil at the edge of the pond and enhance habitat and aesthetic value.

Design Variations

There are several variations of the wet pond design. Some of these design alternatives are intended to make the practice adaptable to various sites and to account for regional constraints and opportunities.

Wet Extended Detention Pond

The wet extended detention pond combines the treatment concepts of the dry extended detention pond and the wet pond. In this design, the water quality volume is split between the permanent pool and detention storage provided above the permanent pool. During storm events, water is detained above the permanent pool and released over 12 to 48 hours. This design has similar pollutant removal to a traditional wet pond and consumes less space. Wet extended detention ponds should be designed to maintain at least half the treatment volume of the permanent pool. In addition, designers need to carefully select vegetation to be planted in the extended detention zone to ensure that the selected vegetation can withstand both wet and dry periods.

<u>Water Reuse Pond</u>

Some designers have used wet ponds to act as a water source, usually for irrigation. In this case, the water balance should account for the water that will be taken from the pond. One study conducted in Florida estimated that a water reuse pond could provide irrigation for a 100-acre golf course at about one-seventh the cost of the market rate of the equivalent amount of water ($40,000 versus $300,000).

Regional Adaptations

<u>Semi-Arid Climates</u>

In arid climates, wet ponds are not a feasible option (see Applicability), but they may possibly be used in semi-arid climates if the permanent pool is maintained with a supplemental water source, or if the pool is allowed to vary seasonally. This choice needs to be seriously evaluated, however. Saunders and Gilroy (1997) reported that 2.6 acre-feet per year of supplemental water were needed to maintain a permanent pool of only 0.29 acre-feet in Austin, Texas.

<u>Cold Climates</u>

Cold climates present many challenges to designers of wet ponds. The spring snowmelt may have a high pollutant load and a large volume to be treated. In addition, cold winters may cause freezing of the permanent pool or freezing at inlets and outlets. Finally, high salt concentrations in runoff resulting from road salting, and sediment loads from road sanding, may impact pond vegetation as well as reduce the storage and treatment capacity of the pond.

One option to deal with high pollutant loads and runoff volumes during the spring snowmelt is the use of a seasonally operated pond to capture snowmelt during the winter, and retain the permanent pool during warmer seasons. In this option, proposed by Oberts (1994), the pond has two water quality outlets, both equipped with gate valves. In the summer, the lower outlet is closed. During the fall and throughout the winter, the lower outlet is opened to draw down the permanent pool. As the spring melt begins, the lower outlet is closed to provide detention for the melt event. This method can act as a substitute for using a minimum extended detention storage volume. When wetlands preservation is a downstream objective, seasonal manipulation of pond levels may not be desired. An analysis of the effects on downstream hydrology should be conducted before considering this option. In addition, the manipulation of this system requires some labor and vigilance; a careful maintenance agreement should be confirmed.

Several other modifications may help to improve the performance of ponds in cold climates. Designers should consider planting the pond with salt-tolerant vegetation if the facility receives road runoff. In order to counteract the effects of freezing on inlet and outlet structures, the use of inlet and outlet structures that are resistant to frost, including weirs and larger diameter pipes, may be useful. Designing structures on-line, with a continuous flow of water through the pond, will also help prevent freezing of these structures. Finally, since freezing of the permanent pool can reduce the effectiveness of pond systems, it may be useful to incorporate extended detention into the design to retain usable treatment area above the permanent pool when it is frozen.

Karst Topography

In karst (i.e., limestone) topography, wet ponds should be designed with an impermeable liner to prevent ground water contamination or sinkhole formation, and to help maintain the permanent pool.

MAINTENANCE

In addition to incorporating features into the pond design to minimize maintenance, some regular maintenance and inspection practices are needed. The table below outlines these practices.

Table 1. Typical maintenance activities for wet ponds (Source: WMI, 1997)

Activity	Schedule
• If wetland components are included, inspect for invasive vegetation.	Semi-annual inspection
• Inspect for damage. • Note signs of hydrocarbon build-up, and deal with appropriately. • Monitor for sediment accumulation in the facility and forebay. • Examine to ensure that inlet and outlet devices are free of debris and operational.	Annual inspection
• Repair undercut or eroded areas.	As needed maintenance
• Clean and remove debris from inlet and outlet structures. • Mow side slopes.	Monthly maintenance
• Manage and harvest wetland plants.	Annual maintenance (if needed)
• Remove sediment from the forebay.	5- to 7-year maintenance
• Monitor sediment accumulations, and remove sediment when the pool volume has become reduced significantly or the pond becomes eutrophic.	20-to 50-year maintenance

EFFECTIVENESS

Structural storm water management practices can be used to achieve four broad resource protection goals. These include flood control, channel protection, ground water recharge, and pollutant removal. Wet ponds can provide flood control, channel protection, and pollutant removal.

Flood Control

One objective of storm water management practices can be to reduce the flood hazard associated with large storm events by reducing the peak flow associated with these storms. Wet ponds can easily be designed for flood control by providing flood storage above the level of the permanent pool.

Channel Protection

When used for channel protection, wet ponds have traditionally controlled the 2-year storm. It appears that this control has been relatively ineffective, and recent research suggests that control of a smaller storm may be more appropriate (MacRae, 1996).

Ground Water Recharge

Wet ponds cannot provide ground water recharge. Infiltration is impeded by the accumulation of debris on the bottom of the pond.

Pollutant Removal

Wet ponds are among the most effective storm water management practices at removing storm water pollutants. A wide range of research is available to estimate the effectiveness of wet ponds. Table 2 summarizes some of the research completed on wet pond removal efficiency. Typical removal rates, as reported by Schueler (1997a) are:
Total Suspended Solids: 67%
Total Phosphorous: 48%
Total Nitrogen: 31%
Nitrate Nitrogen: 24%
Metals: 24–73%
Bacteria: 65%

Table 2: Wet Pond Percent Removal Efficiency Data (Source: USEPA)

Wet Pond Removal Efficiencies							
Study	**TSS**	**TP**	**TN**	**NO_3**	**Metals**	**Bacteria**	**Practice Type**
City of Austin, TX 1991. Woodhollow, TX	54	46	39	45	69–76	46	wet pond
Driscoll 1983. Westleigh, MD	81	54	37	-	26–82	-	wet pond
Dorman et al., 1989. West Pond, MN	65	25	-	61	44–66	-	wet pond
Driscoll, 1983. Waverly Hills, MI	91	79	62	66	57–95	-	wet pond
Driscoll, 1983. Unqua, NY	60	45	-	-	80	86	wet pond
Cullum, 1985. Timber Creek, FL	64	60	15	80	-	-	wet pond
City of Austin, TX 1996. St. Elmo, TX.	92	80	19	17	2–58	89-91	wet pond
Horner, Guedry, and Kortenhoff, 1990. SR 204, WA	99	91	-	-	88–90	-	wet pond
Horner, Guedry, and Kortenhoff, 1990. Seattle, WA	86.7	78.4	-	-	65–67	-	wet pond
Kantrowitz and Woodham, 1995. Saint Joe's Creek, FL	45	45	-	36	38–82	-	wet pond
Wu, 1989. Runaway Bay, NC	62	36	-	-	32–52	-	wet pond
Driscoll 1983. Pitt-AA, MI	32	18	-	7	13–62	-	wet pond
Bannerman and Dodds, 1992. Monroe Street, WI	90	65	-	-	65–75	70	wet pond
Horner, Guedry, and Kortenhoff, 1990. Mercer, WA	75	67	-	-	23–51	-	wet pond
Oberts, Wotzka, and Hartsoe 1989. McKnight, MN	85	48	30	24	67	-	wet pond
Yousef, Wanielista, and Harper 1986. Maitland, FL	-	-	-	87	77–96	-	wet pond
Wu, 1989. Lakeside Pond, NC	93	45	-	-	80–87	-	wet pond
Oberts, Wotzka, and Hartsoe, 1989. Lake Ridge, MN	90	61	41	10	73	-	wet pond
Driscoll, 1983. Lake Ellyn, IL	84	34	-	-	71-78	-	wet pond
Dorman et al., 1989. I-4, FL	54	69	-	97	47–74	-	wet pond
Martin, 1988. Highway Site, FL	83	37	30	28	50–77	-	wet pond
Driscoll, 1983. Grace Street, MI	32	12	6	1	26	-	wet pond
Occoquan Watershed Monitoring Laboratory, 1983. Farm Pond, VA	85	86	34	-	-	-	wet pond
Occoquan Watershed Monitoring Laboratory, 1983. Burke, VA	33.3	39	32	-	38–84	-	wet pond
Dorman et al., 1989. Buckland, CT	61	45	-	22	25 - 51	-	wet pond

Holler, 1989. Boynton Beach Mall, FL	91	76	-	87	-	-	wet pond
Urbonas, Carlson, and Vang 1994. Shop Creek, CO	78	49	12	85	51–57	-	wet pond
Oberts and Wotzka, 1988. McCarrons, MN	91	78	85	-	90	-	wet pond
Gain, 1996. FL	54	30	16	24	42–73	-	wet pond
Ontario Ministry of the Environment, 1991. Uplands, Ontario	82	69	-	-	-	97	wet extended detention pond
Borden et al., 1996. Piedmont, NC	19.6	36.5	35.1	65.9	4 to 97	6	wet extended detention pond
Holler, 1990. Lake Tohopekaliga District, FL	-	85	-	-	-	-	wet extended detention pond
Ontario Ministry of the Environment 1991. Kennedy-Burnett, Ontario	98	79	54	-	21–39	99	wet extended detention pond
Ontario Ministry of the Environment 1991. East Barrhaven, Ontario	52	47	-	-	-	56	wet extended detention pond
Borden et al., 1996. Davis, NC	60.4	46.2	16	18.2	15–51	48	wet extended detention pond

There is considerable variability in the effectiveness of ponds, and it is believed that properly designing and maintaining ponds may help to improve their performance. The siting and design criteria presented in this sheet reflect the best current information and experience to improve the performance of wet ponds. A recent joint project of the American Society of Civil Engineers (ASCE) and the USEPA Office of Water may help to isolate specific design features that can improve performance. The National Stormwater Best Management Practice (BMP) database is a compilation of storm water practices which includes both design information and performance data for various practices. As the database expands, inferences about the extent to which specific design criteria influence pollutant removal may be made. More information on this database is available from the BMP database web page at www.bmpdatabase.org.

COST

Wet ponds are relatively inexpensive storm water practices. The construction costs associated with these facilities range considerably. A recent study (Brown and Schueler, 1997) estimated the cost of a variety of storm water management practices. The study resulted in the following cost equation, adjusting for inflation:

$C = 24.5V^{0.705}$

where:
C = Construction, design and permitting cost;
V = Volume in the pond to include the 10-year storm (ft^3).
Using this equation, typical construction costs are:
$45,700 for a 1 acre-foot facility
$232,000 for a 10 acre-foot facility
$1,170,000 for a 100 acre-foot facility

Ponds do not consume a large area (typically 2–3 percent of the contributing drainage area). Therefore, the land consumed to design the pond will not be very large. It is important to note, however, that these facilities are generally large. Other practices, such as filters or swales, may be "squeezed" into relatively unusable land, but ponds need a relatively large continuous area.

For ponds, the annual cost of routine maintenance is typically estimated at about 3 to 5 percent of the construction cost. Alternatively, a community can estimate the cost of the maintenance activities outlined in the maintenance section. Ponds are long-lived facilities (typically longer than 20 years). Thus, the initial investment into pond systems may be spread over a relatively long time period.

In addition to the water resource protection benefits of wet ponds, there is some evidence to suggest that they may provide an economic benefit by increasing property values. The results of one study suggest that "pond front" property can increase the selling price of new properties by about 10 percent (USEPA, 1995). Another study reported that the perceived value (i.e., the value estimated by residents of a community) of homes was increased by about 15 to 25 percent when located near a wet pond (Emmerling-Dinovo, 1995).

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BMP FACTSHEET
WETLANDS

WETLANDS

Source: Bing Brown, Phoenix Water Services

Water Quantity Benefits (low, medium, high)	
Rate Reduction	**High**
Volume Reduction	**Medium**
Water Quality Benefits (% Reduction)	
Total Suspended Solids (TSS)	**65**
Total Phosphorus (P)	**25**
Total Nitrogen (N)	**20**
Metals	**35-65**
Oils and Grease	**NA**
Bacteria	**NA**
Other Considerations (low, medium, high or other)	
Area Typically Served (acres)	**1 (min)**
% of Area Needed for BMP	**10**
Capital Costs	**Medium-High**
O& M Costs	**Medium**
Maintenance	**Low**
Training	**Low**
Effective Life (years)	**20-50**

DESCRIPTION

Storm water wetlands (a.k.a. constructed wetlands) are structural practices similar to wet ponds (see Wet Pond fact sheet) that incorporate wetland plants into the design. As storm water runoff flows through the wetland, pollutant removal is achieved through settling and biological uptake within the practice. Wetlands are among the most effective storm water practices in terms of pollutant removal and they also offer aesthetic value. Although natural wetlands can sometimes be used to treat storm water runoff that has been properly pretreated, storm water wetlands are fundamentally different from natural wetland systems. Storm water wetlands are designed specifically for the purpose of treating storm water runoff, and typically have less biodiversity than natural wetlands in terms of both plant and animal life. Several design variations of the storm water wetland exist, each design differing in the relative amounts of shallow and deep water, and dry storage above the wetland.

A distinction should be made between using a constructed wetland for storm water management and diverting storm water into a natural wetland. The latter practice is not recommended because altering the hydrology of the existing wetland with additional storm water can degrade the resource and result in plant die-off and the destruction of wildlife habitat. In all circumstances, natural wetlands should be protected from the adverse effects of development, including impacts from increased storm water runoff. This is especially important because natural wetlands provide storm water and flood control benefits on a regional scale.

APPLICABILITY

Constructed wetlands are widely applicable storm water management practices. While they have limited applicability in highly urbanized settings and in arid climates, wetlands have few other restrictions.

Regional Applicability

Storm water wetlands can be applied in most regions of the United States, with the exception of arid climates. In arid and semi-arid climates, it is difficult to design any storm water practice that has a permanent pool. Because storm water wetlands are shallow, a relatively large area is subject to evaporation relative, to the volume of the practice. This makes maintaining the permanent pool in wetlands both more challenging and more important than maintaining the pool of a wet pond (see Wet Pond fact sheet).

Ultra-Urban Areas

Ultra-urban areas are densely developed urban areas in which little pervious surface exists. It is difficult to use wet ponds in the ultra-urban environment because of the land area each wetland consumes. They can, however, be used in an ultra-urban environment if a relatively large area is available downstream of the site.

Storm Water Hot Spots

Storm water hot spots are areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in storm water. A typical example is a gas station. Wetlands can accept runoff from storm water hot spots, but need significant separation from ground water if they will be used for this purpose. Caution also needs to be exercised, if these practices are designed to encourage wildlife use, to ensure that pollutants in storm water runoff do not work their way through the food chain of organisms living in or near the wetland.

Storm Water Retrofit

A storm water retrofit is a storm water management practice (usually structural) put into place after development has occurred, to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. When retrofitting an entire watershed, storm water wetlands have the advantage of providing both educational and habitat value. One disadvantage to wetlands, however, is the difficulty of storing large amounts of runoff without consuming a large amount of land. It is also possible to incorporate wetland elements into existing practices, such as wetland plantings (see Wet Pond and Dry Extended Detention Pond fact sheets)

Cold Water (Trout) Streams

Wetlands pose a risk to cold water systems because of their potential for stream warming. When water remains in the permanent pool, it is heated by the sun. A study in Prince George's County, Maryland, investigated the thermal impacts of a wide range of storm water management practices (Galli, 1990). In this study, only one wetland was investigated, which was an extended detention wetland (see Design Variations). The practice increased the average temperature of storm water runoff that flowed through the practice by about 3°F. As a result, it is likely that wetlands increase water temperature.

ADVANTAGES/LIMITATIONS

Some features of storm water wetlands that may make the design challenging include the following:

- Each wetland consumes a relatively large amount of space, making it an impractical option on many sites.
- Improperly designed wetlands can become a breeding area for mosquitoes.
- Wetlands require careful design and planning to ensure that wetland plants are sustained after the practice is in place.
- It is possible that storm water wetlands may release nutrients during the nongrowing season.
- Designers need to ensure that wetlands do not negatively impact natural wetlands or forest during the design phase.
- Wetlands consume a large amount of land. This characteristic may limit their use in areas where land values are high.

DESIGN AND SITING

In addition to the broad applicability concerns described above, designers need to consider conditions at the site level. In addition, they need to incorporate design features to improve the longevity and performance of the practice, while minimizing the maintenance burden.

Siting Considerations

In addition to the restrictions and modifications to adapting storm water wetlands to different regions and land uses, designers need to ensure that this management practice is feasible at the site in question. The following section provides basic guidelines for siting wetlands.

Drainage Area

Wetlands need sufficient drainage area to maintain the permanent pool. In humid regions, this is typically about 25 acres, but a greater area may be needed in regions with less rainfall.

Slope

Wetlands can be used on sites with an upstream slope of up to about 15 percent. The local slope should be relatively shallow, however. While there is no minimum slope requirement, there does need to be enough elevation drop from the inlet to the outlet to ensure that hydraulic conveyance by gravity is feasible (generally about 3 to 5 feet).

Soils/Topography

Wetlands can be used in almost all soils and geology, with minor design adjustments for regions of karst (i.e. limestone) topography (see Design Considerations).

Ground Water

Unless they receive hot spot runoff, wetlands can often intersect the ground water table. Some research suggests that pollutant removal is reduced when ground water contributes substantially to the pool volume (Schueler, 1997b). It is assumed that wetlands would have a similar response.

Design Considerations

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. There are some features, however, that should be incorporated into most wetland designs. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

Pretreatment

Pretreatment incorporates design features that help to settle out coarse sediment particles. By removing these particles from runoff before they reach the large permanent pool, the maintenance burden of the pond is reduced. In wetlands, pretreatment is achieved with a sediment forebay. A sediment forebay is a small pool (typically about 10 percent of the volume of the permanent pool). Coarse particles remain trapped in the forebay, and maintenance is performed on this smaller pool, eliminating the need to dredge the entire pond.

Treatment

Treatment design features help enhance the ability of a storm water management practice to remove pollutants. The purpose of most of these features is to increase the amount of time and flowpath by which storm water remains in the wetland. Some typical design features include

- The surface area of wetlands should be at least 1 percent of the drainage area to the practice.
- Wetlands should have a length-to-width ratio of at least 1.5:1. Making the wetland longer than it is wide helps prevent "short circuiting" of the practice.
- Effective wetland design displays "complex microtopography." In other words, wetlands should have zones of both very shallow (<6 inches) and moderately shallow (<18 inches) wetlands incorporated, using underwater earth berms to create the zones. This design will provide a longer flow path through the wetland to encourage settling, and it provides two depth zones to encourage plant diversity.

Conveyance

Conveyance of storm water runoff into and through a storm water management practice is a critical component of any practice. Storm water should be conveyed to and from practices safely and to minimize erosion potential. The outfall of pond systems should always be stabilized to prevent scour. In addition, an emergency spillway should be provided to safely convey large flood events. To help mitigate warming at the outlet channel, designers should provide shade around the channel at the pond outlet.

Maintenance Reduction

In addition to regular maintenance activities needed to maintain the function of storm water practices, some design features can be incorporated to ease the maintenance burden of each practice. In wetlands, maintenance reduction features include techniques to reduce the amount of maintenance needed, as well as techniques to make regular maintenance activities easier.

One potential maintenance concern in wet ponds is clogging of the outlet. Wetlands should be designed with a nonclogging outlet such as a reverse-slope pipe or a weir outlet with a trash rack. A reverse-slope pipe draws from below the permanent pool extending in a reverse angle up to the riser and establishes the water elevation of the permanent pool. Because these outlets draw water from below the level of the permanent pool, they are less likely to be clogged by floating debris. Another general rule is that no orifice should be less than 3 inches in diameter. Smaller orifices are generally more susceptible to clogging, without specific design considerations to reduce this problem. Another feature that can help reduce the potential for clogging of the outlet is to incorporate a small pool, or "micropool" at the outlet.

Design features are also incorporated to ease maintenance of both the forebay and the main pool of wetlands. Wetlands should be designed with a maintenance access to the forebay to ease this relatively routine (5- to 7-year) maintenance activity. In addition, the permanent pool should have a pond drain to draw down the pond for the more infrequent dredging of the main cell of the wetland.

Landscaping

Landscaping of wetlands can make them an asset to a community and can also enhance the pollutant removal of the practice. In wetland systems, landscaping is an integral part of the design. To ensure the establishment and survival of wetland plants, a landscaping plan should provide detailed information about the plants selected, when they will be planted, and a strategy for maintaining them. The plan should detail wetland plants, as well as vegetation to be established adjacent to the wetland.

A variety of techniques can be used to establish wetland plants. The most effective techniques are the use of nursery stock as dormant rhizomes, live potted plants, and bare rootstock. A "wetland mulch," soil from a natural wetland or a designed "wetland mix," can be used to supplement wetland plantings or alone to establish wetland vegetation. Wetland mulch carries with it the seed bank from the original wetland, and can help to enhance diversity in the wetland. The least expensive option to establish wetlands is to allow the wetland to colonize itself. One disadvantage to this last technique is that invasive species such as cattails or Phragmites may dominate the wetland.

When developing a plan for wetland planting, care needs to be taken to ensure that plants are established in the proper depth and within the planting season. This season varies regionally, and is generally between 2 and 3 months long in the spring to early summer. Plant lists are available for various regions of the United States through wetland nurseries, extension services, and conservation districts.

Design Variations

There are several variations of the wetland design. The designs are characterized by the volume of the wetland in deep pool, high marsh, and low marsh, and whether the design allows for detention of small storms above the wetland surface. Other design variations help to make wetland designs practical in cold climates.

Shallow Marsh

In the shallow marsh design, most of the wetland volume is in the relatively shallow high marsh or low marsh depths. The only deep portions of the shallow wetland design are the forebay at the inlet to the wetland and the micropool at the outlet. One disadvantage to this design is that, since the pool is very shallow, a large amount of land is typically needed to store the water quality volume (i.e., the volume of runoff to be treated in the wetland).

Extended Detention Wetland

This design is the same as the shallow marsh, with additional storage above the surface of the marsh. Storm water is temporarily ponded above the surface in the extended detention zone for between 12 and 24 hours. This design can treat a greater volume of storm water in a smaller space than the shallow wetland design. In the extended detention wetland option, plants that can tolerate wet and dry periods should be specified in the extended detention zone.

Pond/Wetland System

The pond/wetland system combines the wet pond (see Wet Retention Pond fact sheet) design with a shallow marsh. Storm water runoff flows through the wet pond and into the shallow marsh. This design requires less surface area than the shallow marsh because some of the volume of the practice is in the relatively deep (i.e., 6–8 feet) pond.

Gravel-Based Wetlands

In this design, runoff flows through a rock filter with wetland plants at the surface. Pollutants are removed through biological activity on the surface of the rocks, as well as by pollutant uptake of the plants. This practice is fundamentally different from other wetland designs because, while most wetland designs behave like wet ponds with differences in grading and landscaping, gravel-based wetlands are more similar to a filtering system.

Regional Variations

Cold Climates

Cold climates present many challenges to designers of wetlands. During the spring snowmelt, a large volume of water runs off in a short time, carrying a relatively high pollutant load. In addition, cold winter temperatures may cause freezing of the permanent pool or freezing at inlets and outlets. Finally, high salt concentrations in runoff resulting from road salting, as well as sediment loads from road sanding, may impact wetland vegetation.

One of the greatest challenges of storm water wetlands, particularly shallow marshes, is that much of the practice is very shallow. Therefore, much of the volume in the wetland can be lost as the surface of the practice freezes. One study found that the performance of a wetland system was diminished during the spring snowmelt because the outlet and surface of the wetland had frozen. Sediment and pollutants in snowmelt and rainfall events "skated" over the surface of the wetland, depositing at the outlet of the wetland. When the ice melted, this sediment was washed away by storm events (Oberts, 1994). Several design features can help minimize this problem, including:

- "On-line" designs allowing flow to move continuously can help prevent outlets from freezing.
- Wetlands should be designed with multiple cells, with a berm or weir separating each cell. This modification will help to retain storage for treatment above the ice layer during the winter season.
- Outlets that are resistant to freezing should be used. Some examples include weirs or pipes with large diameters.

The salt and sand used to remove ice from roads and parking lots may also create a challenge to designing wetlands in cold climates. When wetlands drain highway runoff, or parking lots, salt-tolerant vegetation, such as pickle weed or cord grass should be used. (Contact a local nursery or extension agency for more information in your region). In addition, designers should consider using a large forebay to capture the sediment from road sanding.

Karst Topography

In karst (i.e., limestone) topography, wetlands should be designed with an impermeable liner to prevent ground water contamination or sinkhole formation, and to help maintain the permanent pool.

MAINTENANCE

In addition to incorporating features into the wetland design to minimize maintenance, some regular maintenance and inspection practices are needed. Table 1 outlines these practices.

Table 1. Regular maintenance activities for wetlands (Source: Adapted from WMI, 1997, and CWP, 1998)

Activity	Schedule
• Replace wetland vegetation to maintain at least 50% surface area coverage in wetland plants after the second growing season.	One-time
• Inspect for invasive vegetation and remove where possible.	Semi-annual inspection
• Inspect for damage to the embankment and inlet/outlet structures. Repair as necessary. • Note signs of hydrocarbon build-up, and deal with appropriately. • Monitor for sediment accumulation in the facility and forebay. • Examine to ensure that inlet and outlet devices are free of debris and are operational.	Annual inspection
• Repair undercut or eroded areas.	As needed maintenance
• Clean and remove debris from inlet and outlet structures. • Mow side slopes.	Frequent (3–4 times/year) maintenance
• Supplement wetland plants if a significant portion have not established (at least 50% of the surface area). • Harvest wetland plants that have been "choked out" by sediment build-up.	Annual maintenance (if needed)
• Remove sediment from the forebay.	5- to 7-year maintenance
• Monitor sediment accumulations, and remove sediment when the pool volume has become reduced significantly, plants are "choked" with sediment, or the wetland becomes eutrophic.	20- to 50-year maintenance

EFFECTIVENESS

Structural storm water management practices can be used to achieve four broad resource protection goals. These include flood control, channel protection, ground water recharge, and pollutant removal. Wetlands can provide flood control, channel protection, and pollutant removal.

Flood Control

One objective of storm water management practices can be to reduce the flood hazard associated with large storm events by reducing the peak flow associated with these storms. Wetlands can easily be designed for flood control by providing flood storage above the level of the permanent pool.

Channel Protection

When used for channel protection, wetlands have traditionally controlled the 2-year storm. It appears that this control has been relatively ineffective, and recent research suggests that control of a smaller storm may be more appropriate (MacRae, 1996).

Ground Water Recharge

Wetlands cannot provide ground water recharge. The build-up of debris at the bottom of the wetland prevents the movement of water into the subsoil.

Pollutant Removal

Wetlands are among the most effective storm water management practices at removing storm water pollutants. A wide range of research is available to estimate the effectiveness of wetlands. Wetlands have high pollutant removal rates, and are more effective than any other practice at removing nitrate and bacteria. Table 2 provides pollutant removal data derived from the Center for Watershed Protection's National Pollutant Removal Database for Stormwater Treatment Practices (Winer, 2000).

Table 2. Typical Pollutant Removal Rates of Wetlands (%) (Winer, 2000)

Pollutant	**Stormwater Treatment Practice Design Variation**			
	Shallow Marsh	ED Wetland[1]	Pond/Wetland System	Submerged Gravel Wetland[1]
TSS	83±51	69	71±35	83
TP	43±40	39	56±35	64
TN	26±49	56	19±29	19
NOx	73±49	35	40±68	81
Metals	36–85	(-80)–63	0–57	21–83
Bacteria	76[1]	NA	NA	78

[1]Data based on fewer than five data points

The effectiveness of wetlands varies considerably, but many believe that proper design and maintenance might help to improve their performance. The siting and design criteria presented in this sheet reflect the best current information and experience to improve the performance of wetlands. A recent joint project of the American Society of Civil Engineers (ASCE) and the U.S. EPA Office of Water may help to isolate specific design features that can improve performance. The National Stormwater Best Management Practice (BMP) database is a compilation of storm water practices which includes both design information and performance data for various practices. As the database expands, inferences about the extent to which specific design criteria influence pollutant removal may be made. More information on this database is available on the BMP database web page at http://www.bmpdatabase.org

COST

Wetlands are relatively inexpensive storm water practices. Construction cost data for wetlands are rare, but one simplifying assumption is that they are typically about 25 percent more expensive than storm water ponds of an equivalent volume. Using this assumption, an equation developed by Brown and Schueler (1997) to estimate the cost of wet ponds can be modified to estimate the cost of storm water wetlands using the equation:

$C = 30.6V^{0.705}$

where:

C = Construction, design, and permitting cost;

V = Wetland volume needed to control the 10-year storm (ft^3).

Using this equation, typical construction costs are the following:

$ 57,100 for a 1 acre-foot facility

$ 289,000 for a 10 acre-foot facility

$ 1,470,000 for a 100 acre-foot facility

Wetlands consume about 3 to 5 percent of the land that drains to them, which is relatively high compared with other storm water management practices. In areas where land value is high, this may make wetlands an infeasible option.

For wetlands, the annual cost of routine maintenance is typically estimated at about 3 percent to 5 percent of the construction cost. Alternatively, a community can estimate the cost of the maintenance activities outlined in the maintenance section. Wetlands are long-lived facilities (typically longer than 20 years). Thus, the initial investment into these systems may be spread over a relatively long time period.

Although no studies are available on wetlands in particular, there is some evidence to suggest that wet ponds may provide an economic benefit by increasing property values. The results of one study suggest that "pond frontage" property can increase the selling price of new properties by about 10 percent (USEPA, 1995). Another study reported that the perceived value (i.e., the value estimated by residents of a community) of homes was increased by about 15 to 25 percent when located near a wet pond (Emmerling-Dinovo, 1995). It is anticipated that well-designed wetlands, which incorporate additional aesthetic features, would have the same benefit.

REFERENCES

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BMP FACTSHEET
INFILTRATION TRENCH

INFILTRATION TRENCH

Source: California Storm Water Quality Association

Water Quantity Benefits (low, medium, high)	
Rate Reduction	**High**
Volume Reduction	**High**

Water Quality Benefits (% Reduction)	
Total Suspended Solids (TSS)	**75-90**
Total Phosphorus (P)	**50-70**
Total Nitrogen (N)	**45-60**
Metals	**75-90**
Oil and Grease	**NA**
Bacteria	**70-80**

Other Considerations (low, medium, high or other)	
Area Typically Served (acres)	**2-4**
% of Area Needed for BMP	**2-4**
Capital Costs	**Medium**
O& M Costs	**Medium**
Maintenance	**Medium**
Training	**Medium**
Effective Life (years)	**10-15**

DESCRIPTION

An infiltration trench (a.k.a. infiltration galley) is a rock-filled trench with no outlet that receives storm water runoff. Storm water runoff passes through some combination of pretreatment measures, such as a swale and detention basin, and into the trench. There, runoff is stored in the void space between the stones and infiltrates through the bottom and into the soil matrix. The primary pollutant removal mechanism of this practice is filtering through the soil.

APPLICABILITY

Infiltration trenches have select applications. While they can be applied in most regions of the country, their use is sharply restricted by concerns due to common site factors, such as potential ground water contamination, soils, and clogging.

Regional Applicability

Infiltration trenches can be utilized in most regions of the country, with some design modifications in cold and arid climates. In regions of karst (i.e., limestone) topography, these storm water management practices may not be applied due to concerns of sink hole formation and ground water contamination.

Ultra-Urban Areas

Ultra-urban areas are densely developed urban areas in which little pervious surface exists. Infiltration trenches can sometimes be applied in the ultra-urban environment. Two features that can restrict their use are the potential of infiltrated water to interfere with existing infrastructure, and the relatively poor infiltration of most urban soils.

Storm Water Hot Spots

Storm water hot spots are areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in storm water. Infiltration trenches should not receive runoff from storm water hot spots, unless the storm water has already been treated by another storm water management practice, because of potential ground water contamination.

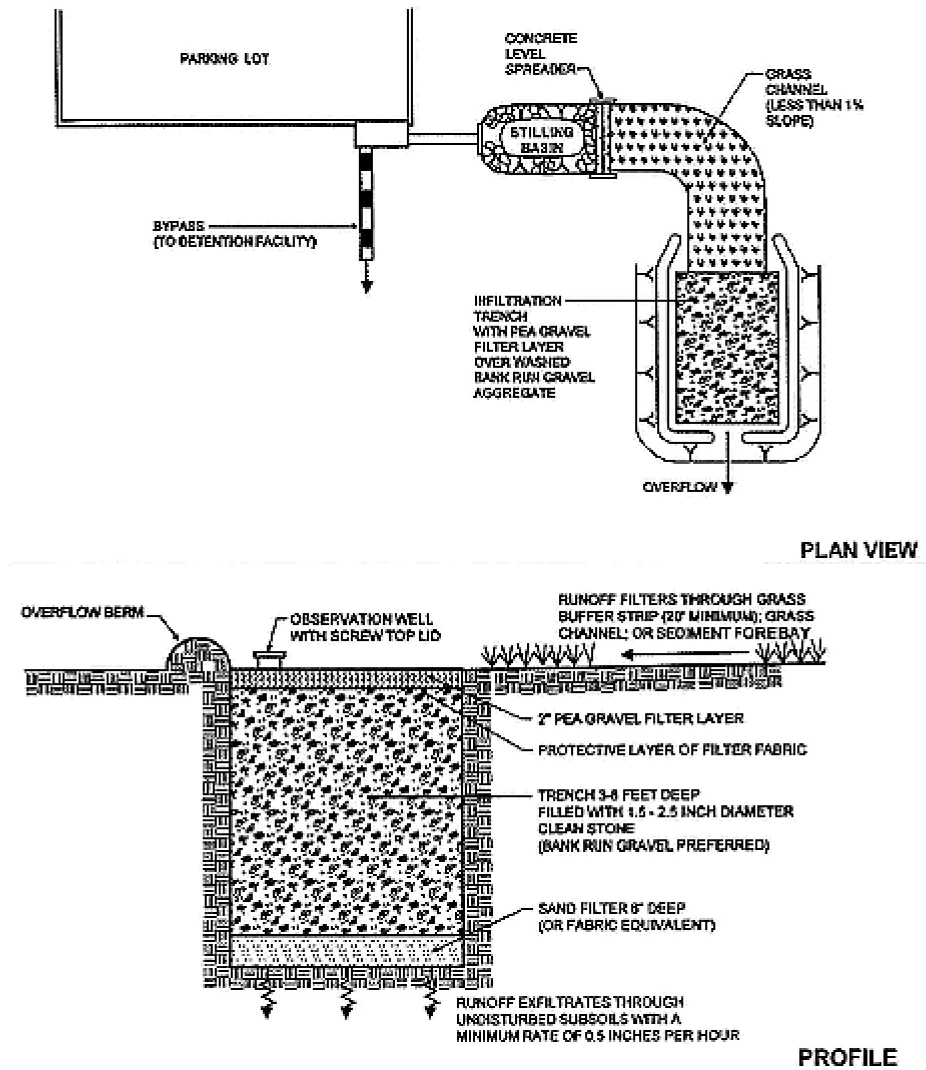
ADVANTAGES/LIMITATIONS

Although infiltration trenches can be a useful management practice, they have several limitations. While they do not detract visually from a site, infiltration trenches provide no visual enhancements. Their application is limited due to concerns over ground water contamination and other soils requirements. Finally, maintenance can be burdensome, and infiltration practices have a relatively high rate of failure.

DESIGN AND SITING

Infiltration trenches have select applications. Although they can be applied in a variety of situations, the use of infiltration trenches is restricted by concerns over ground water contamination, soils, and clogging.

INFILTRATION TRENCH



A schematic of an infiltration trench (Source: MDE, 2000)

Siting Considerations

Infiltration practices need to be sited extremely carefully. In particular, designers need to ensure that the soils on site are appropriate for infiltration and that designs minimize the potential for ground water contamination and long-term maintenance.

<u>Drainage Area</u>

Infiltration trenches generally can be applied to relatively small sites (less than 5 acres), with relatively high impervious cover. Application to larger sites generally causes clogging, resulting in a high maintenance burden.

Slope

Infiltration trenches should be placed on flat ground, but the slopes of the site draining to the practice can be as steep as 15 percent.

Soils/Topography

Soils and topography are strongly limiting factors when locating infiltration practices. Soils must be significantly permeable to ensure that the storm water can infiltrate quickly enough to reduce the potential for clogging. In addition, soils that infiltrate too rapidly may not provide sufficient treatment, creating the potential for ground water contamination. The infiltration rate should range between 0.5 and 3 inches per hour. In addition, the soils should have no greater than 20-percent clay content, and less than 40-percent silt/clay content (MDE, 2000). The infiltration rate and textural class of the soil need to be confirmed in the field; designers should not rely on more generic information such as a soil survey. Finally, infiltration trenches may not be used in regions of karst topography, due to the potential for sinkhole formation or ground water contamination.

Ground Water

Designers always need to provide significant separation (2 to 5 feet) from the bottom of the infiltration trench and the seasonally high ground water table, to reduce the risk of contamination. In addition, infiltration practices should be separated from drinking water wells.

Design Considerations

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. There are some features, however, that should be incorporated into most infiltration trench designs. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

Pretreatment

Pretreatment refers to design features that provide settling of large particles before runoff reaches a management practice, easing the long-term maintenance burden. Pretreatment is important for all structural storm water management practices, but it is particularly important for infiltration practices. To ensure that pretreatment mechanisms are effective, designers should incorporate "multiple pretreatment," using practices such as grassed swales, vegetated filter strips, detention, or a plunge pool in series.

Treatment

Treatment design features enhance the pollutant removal of a practice. During the construction process, the upland soils of infiltration trenches need to be stabilized to ensure that the trench does not become clogged with sediment. Furthermore, the practice should be filled with large clean stones that can retain the volume of water to be treated in their voids. Like infiltration basins, this practice should be sized so that the volume to be treated can infiltrate out of the trench bottom in 24 hours.

Conveyance

Storm water needs to be conveyed through storm water management practices safely, and in a way that minimizes erosion. Designers need to be particularly careful in ensuring that channels leading to an infiltration practice are designed to minimize erosion. Infiltration trenches should be designed to treat only small storms, (i.e., only for water quality). Thus, these practices should be designed "off-line," using a structure to divert only small flows to the practice. Finally, the sides of an infiltration trench should be lined with a geotextile fabric to prevent flow from causing rills along the edge of the practice.

Maintenance Reduction

In addition to regular maintenance activities, designers also need to incorporate features into the design to ensure that the maintenance burden of a practice is reduced. These features can make regular maintenance activities easier or reduce the need to perform maintenance. As with all management practices, infiltration trenches should have an access path for maintenance activities. An observation well (i.e., a perforated PVC pipe that leads to the bottom of the trench) can enable inspectors to monitor the drawdown rate. Where possible, trenches should have a means to drain the practice if it becomes clogged, such as an underdrain. An underdrain is a perforated pipe system in a gravel bed, installed on the bottom of filtering practices to collect and remove filtered runoff. An underdrain pipe with a shutoff valve can be used in an infiltration system to act as an overflow in case of clogging.

Landscaping

In infiltration trenches, there is no landscaping on the practice itself, but it is important to ensure that the upland drainage is properly stabilized with thick vegetation, particularly following construction.

Regional Variations

Arid or Semi-Arid Climates

In arid regions, infiltration practices are often highly recommended because of the need to recharge the ground water. One concern in these regions is the potential of these practices to clog, due to relatively high sediment concentrations in these environments. Pretreatment needs to be more heavily emphasized in these dryer climates.

Cold Climates

In extremely cold climates (i.e., regions that experience permafrost), infiltration trenches may be an infeasible option. In most cold climates, infiltration trenches can be a feasible management practice, but there are some challenges to their use. The volume may need to be increased in order to treat snowmelt. In addition, if the practice is used to treat roadside runoff, it may be desirable to divert flow around the trench in the winter to prevent infiltration of chlorides from road salting, where this is a problem. Finally, a minimum setback from roads is needed to ensure that the practice does not cause frost heaving.

MAINTENANCE

In addition to incorporating features into the design to minimize maintenance, some regular maintenance and inspection practices are needed. Table 1 outlines some of these practices.

Table 1: Typical maintenance activities for infiltration trenches (Source: Modified from WMI, 1997)

Activity	Schedule
• Check observation wells following 3 days of dry weather. Failure to percolate within this time period indicates clogging. • Inspect pretreatment devices and diversion structures for sediment build-up and structural damage.	Semi-annual inspection
• Remove sediment and oil/grease from pretreatment devices and overflow structures.	Standard maintenance
• If bypass capability is available, it may be possible to regain the infiltration rate in the short term by using measures such as providing an extended dry period.	5-year maintenance
• Total rehabilitation of the trench should be conducted to maintain storage capacity within 2/3 of the design treatment volume and 72-hour exfiltration rate limit. • Trench walls should be excavated to expose clean soil.	Upon failure

Infiltration practices have historically had a high rate of failure compared to other storm water management practices. One study conducted in Prince George's County, Maryland (Galli, 1992), revealed that less than half of the infiltration trenches investigated (of about 50) were still functioning properly, and less than one-third still functioned properly after 5 years. Many of these practices, however, did not incorporate advanced pretreatment. By carefully selecting the location and improving the design features of infiltration practices, their performance should improve.

EFFECTIVENESS

Structural storm water management practices can be used to achieve four broad resource protection goals. These include flood control, channel protection, ground water recharge, and pollutant removal. Infiltration trenches can provide ground water recharge, pollutant control, and can help somewhat to provide channel protection.

Ground Water Recharge

Infiltration trenches recharge the ground water because runoff is treated for water quality by filtering through the soil and discharging to ground water.

Pollutant Removal

Very little data are available regarding the pollutant removal associated with infiltration trenches. It is generally assumed that they have very high pollutant removal, because none of the storm water entering the practice remains on the surface. Schueler (1987) estimated pollutant removal for infiltration trenches based on data from land disposal of wastewater. The average pollutant removal, assuming the infiltration trench is sized to treat the runoff from the given storm, is:

Table 2: Estimated pollutant removal effectiveness for water quality trenches (%)

INFILTRATION TRENCH

TSS	TP	TN	Metals	BOD	Bacteria	Comments
75	50 - 55	45 - 55	75 - 80	70	75	Capture of 0.5 in of runoff (first flush)
75	60 - 70	55 - 60	85 - 90	75	90	Capture of 1 in of runoff
90	60 - 70	55 - 60	85 - 90	80	90	Capture of 2 in of runoff
Source: Schueler (1987).						

These removal efficiencies assume that the infiltration trench is well designed and maintained. The information in the Siting and Design Considerations and Maintenance Considerations sections represent the best available information on how to properly design these practices. The design references below provide additional information.

COST

Infiltration trenches are somewhat expensive, when compared to other storm water practices, in terms of cost per area treated. Typical construction costs, including contingency and design costs, are about $5 per ft^3 of storm water treated (SWRPC, 1991; Brown and Schueler, 1997).

Infiltration trenches typically consume about 2 to 3 percent of the site draining to them, which is relatively small. In addition, infiltration trenches can fit into thin, linear areas. Thus, they can generally fit into relatively unusable portions of a site.

One cost concern associated with infiltration practices is the maintenance burden and longevity. If improperly maintained, infiltration trenches have a high failure rate (see Maintenance Considerations). In general, maintenance costs for infiltration trenches are estimated at between 5 percent and 20 percent of the construction cost. More realistic values are probably closer to the 20-percent range, to ensure long-term functionality of the practice.

REFERENCES

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BMP FACTSHEET
INFILTRATION BASINS

INFILTRATION BASINS

Source: Pennsylvania Department of Environmental Protection

Water Quantity Benefits (low, medium, high)	
Rate Reduction	**High**
Volume Reduction	**High**
Water Quality Benefits (% Reduction)	
Total Suspended Solids (TSS)	**75-99**
Total Phosphorus (P)	**50-70**
Total Nitrogen (N)	**45-70**
Metals	**50-90**
Oil and Grease	**NA**
Bacteria	**75-98**
Other Considerations (low, medium, high or other)	
Area Typically Served (acres)	**2-20**
% of Area Needed for BMP	**2-4**
Capital Costs	**Medium**
O& M Costs	**Medium**
Maintenance	**Medium**
Training	**Low**
Effective Life (years)	**5-10 (before deep tilling)**

DESCRIPTION

An infiltration basin is a shallow impoundment which is designed to infiltrate storm water into the ground water. This practice is believed to have a high pollutant removal efficiency and can also help recharge the ground water, thus restoring low flows to stream systems. Infiltration basins can be challenging to apply on many sites, however, because of soils requirements. In addition, some studies have shown relatively high failure rates compared with other management practices.

APPLICABILITY

Infiltration basins have select applications. Their use is often sharply restricted by concerns over ground water contamination, soils, and clogging at the site.

Regional Applicability

Infiltration basins can be utilized in most regions of the country, with some design modifications in cold and arid climates. In regions of karst (i.e., limestone) topography, these storm water management practices may not be applied due to concerns of sink hole formation and ground water contamination.

Ultra-Urban Areas

Ultra-urban areas are densely developed urban areas in which little pervious surface exists. In these areas, few storm water practices can be easily applied due to space limitations. Infiltration basins can rarely be applied in the ultra-urban environment.

Two features that can restrict their use are the potential of infiltrated water to interfere with existing infrastructure, and the relatively poor infiltration capacity of most urban soils. In addition, while they consume only the space of the infiltration basin site itself, they need a continuous, relatively flat area. Thus, it is more difficult to fit them into small unusable areas on a site.

Storm Water Hot Spots

A storm water hot spot is an area where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in storm water. Infiltration basins should never receive runoff from storm water hot spots, unless the storm water has already been treated by another practice. This caution is due to potential ground water contamination.

Storm Water Retrofit

A storm water retrofit is a storm water practice (usually structural) put into place after development has occurred, to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. Infiltration basins have limited applications as a storm water retrofit. Their use is restricted by three factors. First, infiltration basins should be used to treat small sites (less than 5 acres). Practices that are applied to small sites, such as infiltration basins, are generally a high-cost retrofit option in terms of construction cost and the maintenance burden associated with the large number of practices needed to retrofit a watershed. Second, it is often difficult to find areas where soils are appropriate for infiltration in an already urban or suburban environment. Finally, infiltration basins are best applied to small sites, yet need a flat, relatively continuous area. It is often difficult to find sites with this type of area available.

Cold Water (Trout) Streams

Infiltration basins are an excellent option for cold water streams because they encourage infiltration of storm water and maintain dry weather flow. Because storm water travels underground to the stream, it has little opportunity to increase in temperature.

ADVANTAGES/LIMITATIONS

Although infiltration basins can be useful practices, they have several limitations. Infiltration basins are not generally aesthetic practices, particularly if they clog. If they clog, the soils become saturated, and the practice can be a source of mosquitoes. In addition, these practices are challenging to apply because of concerns over ground water contamination and sufficient soil infiltration. Finally, maintenance of infiltration practices can be burdensome, and they have a relatively high rate of failure.

DESIGN AND SITING

When designing infiltration basins, designers need to carefully consider both the restrictions on the site and design features to improve the long-term performance of the practice.

Siting Considerations

Infiltration practices need to be located extremely carefully. In particular, designers need to ensure that the soils on the site are appropriate for infiltration, and that designs minimize the potential for ground water contamination and long-term maintenance problems.

Drainage Area

Infiltration basins have historically been used as regional facilities, serving for both quantity and quality control. In some regions of the country, this practice is feasible, particularly if the soils are particularly sandy. In most areas, however, infiltration basins experience high rates of failure when used in this manner. In general, the practice is best applied to relatively small drainage areas (i.e., less than 10 acres).

Slope

The bottom of infiltration basins needs to be completely flat to allow infiltration throughout the entire basin bottom.

Soils/Topography

Soils and topography are strongly limiting factors when locating infiltration practices. Soils must be significantly permeable to ensure that the practice can infiltrate quickly enough to reduce the potential for clogging, and soils that infiltrate too rapidly may not provide sufficient treatment, creating the potential for ground water contamination. The infiltration rate should range between 0.5 and 3 inches per hour. In addition, the soils should have no greater than 20 percent clay content, and less than 40 percent silt/clay content (MDE, 2000). Finally, infiltration basins may not be used in regions of karst topography, due to the potential for sinkhole formation or ground water contamination.

Ground Water

Designers always need to provide significant separation distance (2 to 5 feet) from the bottom of the infiltration basin and the seasonally high ground water table, to reduce the risk of contamination. Infiltration practices should also be separated from drinking water wells.

Design Considerations

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. There are some features, however, that should be incorporated into most infiltration basin designs. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

Pretreatment

Pretreatment refers to design features that provide settling of large particles before runoff reaches a management practice, easing the long-term maintenance burden. Pretreatment is important for all structural management practices, but it is particularly important for infiltration practices. In order to ensure that pretreatment mechanisms are effective, designers should incorporate "multiple pretreatment," using practices such as grassed swales, sediment basins, and vegetated filter strips in series.

Treatment

Treatment design features enhance the pollutant removal of a practice. For infiltration practices, designers need to stabilize upland soils to ensure that the basin does not become clogged with sediment. In addition, the facility needs to be sized so that the volume of water to be treated infiltrates through the bottom in a given amount of time. Because infiltration basins are designed in this manner, infiltration basins designed on less permeable soils should be significantly larger than those designed on more permeable soils.

Conveyance

Storm water needs to be conveyed through storm water management practices safely and in a way that minimizes erosion. Designers need to be particularly careful in ensuring that channels leading to an infiltration practice are designed to minimize erosion. In general, infiltration basins should be designed to treat only small storms (i.e., only for water quality). Thus, these practices should be designed "off-line," using a flow separator to divert only small flows to the practice.

Maintenance Reduction

In addition to regular maintenance activities, designers also need to incorporate features into the design to ensure that the maintenance burden of a practice is reduced. These features can make regular maintenance activities easier or reduce the need to perform maintenance. In infiltration basins, designers need to provide access to the basin for regular maintenance activities. Where possible, a means to drain the basin, such as an underdrain, should be provided in case the bottom becomes clogged. This feature allows the basin to be drained and accessed for maintenance in the event that the water has ponded in the basin bottom or the soil is saturated.

Landscaping

Landscaping can enhance the aesthetic value of storm water practices or improve their function. In infiltration basins, the most important purpose of vegetation is to reduce the tendency of the practice to clog. Upland drainage needs to be properly stabilized with a thick layer of vegetation, particularly immediately following construction. In addition, providing a thick turf at the basin bottom helps encourage infiltration and prevent the formation of rills in the basin bottom.

Design Variations

Some modifications may be needed to ensure the performance of infiltration basins in arid and cold climates.

Arid or Semi-Arid Climates

In arid regions, infiltration practices are often highly recommended because of the need to recharge the ground water. In arid regions, designers need to emphasize pretreatment even more strongly to ensure that the practice does not clog, because of the high sediment concentrations associated with storm water runoff in areas such as the Southwest. In addition, the basin bottom may be planted with drought-tolerant species and/or covered with an alternative material such as sand or gravel.

Cold Climates

In extremely cold climates (i.e., regions that experience permafrost), infiltration basins may be an infeasible option. In most cold climates, infiltration basins can be a feasible practice, but there are some challenges to its use. First, the practice may become inoperable during some portions of the year when the surface of the basin becomes frozen. Other design features also may be incorporated to deal with the challenges of cold climates. One such challenge is the volume of runoff associated with the spring snowmelt event. The capacity of the infiltration basin might be increased to account for snowmelt volume.

Another option is the use of a seasonably operated facility (Oberts, 1994). A seasonally operated infiltration/detention basin combines several techniques to improve the performance of infiltration practices in cold climates. Two features, the underdrain system and level control valves, are useful in cold climates. These features are used as follows: At the beginning of the winter season, the level control valve is opened and the soil is drained. As the snow begins to melt in the spring, the underdrain and the level control valves are closed. The snowmelt is infiltrated until the capacity of the soil is reached. Then, the facility acts as a detention facility, providing storage for particles to settle.

Other design features can help to minimize problems associated with winter conditions, particularly concerns that chlorides from road salting may contaminate ground water. The basin may be disconnected during the winter to ensure that chlorides do not enter the ground water in areas where this is a problem, or if the basin is used to treat roadside runoff. Designers may also want to reconsider application of infiltration practices on parking lots or roads where deicing is used, unless it is confirmed that the practice will not cause elevated chloride levels in the ground water. If the basin is used for snow storage, or to treat roadside or parking lot runoff, the basin bottom should be planted with salt-tolerant vegetation.

MAINTENANCE

Regular maintenance is critical to the successful operation of infiltration basins (see Table 1). Historically, infiltration basins have had a poor track record. In one study conducted in Prince George's County, Maryland (Galli, 1992), all of the infiltration basins investigated clogged within 2 years. This trend may not be the same in soils with high infiltration rates, however. A study of 23 infiltration basins in the Pacific Northwest showed better long-term performance in an area with highly permeable soils (Hilding, 1996). In this study, few of the infiltration basins had failed after 10 years.

Table 1. Typical maintenance activities for infiltration basins (Source: Modified from WMI, 1997)

Activity	Schedule
• Inspect facility for signs of wetness or damage to structures • Note eroded areas. • If dead or dying grass on the bottom is observed, check to ensure that water percolates 2–3 days following storms. • Note signs of petroleum hydrocarbon contamination and handle properly.	Semi-annual inspection
• Mow and remove litter and debris. • Stabilize of eroded banks. • Repair undercut and eroded areas at inflow and outflow structures.	Standard maintenance (as needed)
• Disc or otherwise aerate bottom. • Dethatch basin bottom.	Annual maintenance
• Scrape bottom and remove sediment. Restore original cross-section and infiltration rate. • Seed or sod to restore ground cover.	5-year maintenance

EFFECTIVENESS

Structural management practices can be used to achieve four broad resource protection goals. These include flood control, channel protection, ground water recharge, and pollutant removal. Infiltration basins can provide ground water recharge and pollutant removal.

Ground Water Recharge

Infiltration basins recharge the ground water because runoff is treated for water quality by filtering through the soil and discharging to ground water.

Pollutant Removal

Very little data are available regarding the pollutant removal associated with infiltration basins. It is generally assumed that they have very high pollutant removal because none of the storm water entering the practice remains on the surface. Schueler (1987) estimated pollutant removal for infiltration basins based on data from land disposal of wastewater.

The removal efficiencies given on page one assume that the infiltration basin is well designed and maintained. The information in the Siting and Design Considerations and Maintenance Considerations sections represent the best available information on how to properly design these practices. The design references below also provide additional information.

COST

Infiltration basins are relatively cost-effective practices because little infrastructure is needed when constructing them. One study estimated the total construction cost at about $2 per ft^3 (adjusted for inflation) of storage for a 0.25-acre basin (SWRPC, 1991). Infiltration basins typically consume about 2 to 3 percent of the site draining to them, which is relatively small. Maintenance costs are estimated at 5 to 10 percent of construction costs.

One cost concern associated with infiltration practices is the maintenance burden and longevity. If improperly maintained, infiltration basins have a high failure rate (see Maintenance Considerations). Thus, it may be necessary to replace the basin after a relatively short period of time.

INFILTRATION BASINS

REFERENCES

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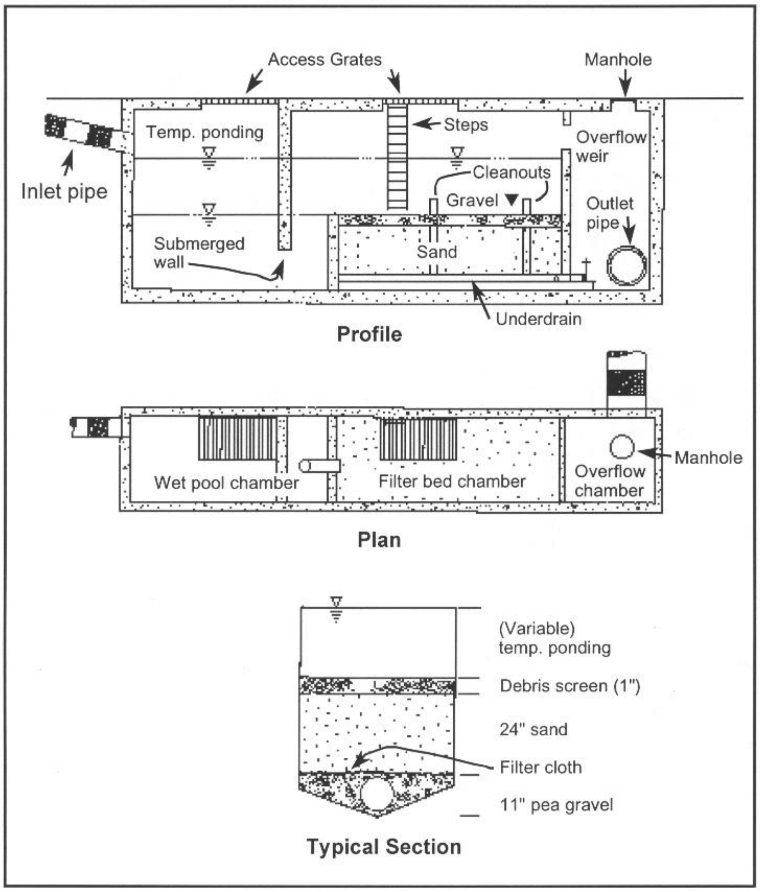
BMP FACTSHEET
UNDERGROUND SAND FILTERS

UNDERGROUND SAND FILTERS



Source: Claytor and Schueler, 1996.

Water Quantity Benefits (low, medium, high)	
Rate Reduction	Medium
Volume Reduction	Low
Water Quality Benefits (% Reduction)	
Total Suspended Solids (TSS)	70-90
Total Phosphorus (P)	43-70
Total Nitrogen (N)	30-50
Metals	22-91
Oil and Grease	NA
Bacteria	NA
Other Considerations (low, medium, high or other)	
Area Typically Served (acres)	2-5
% of Area Needed for BMP	2-3
Capital Costs	Medium
O& M Costs	High
Maintenance	Medium
Training	Medium
Effective Life (years)	5-20

DESCRIPTION

Sand filters are usually two-chambered storm water practices; the first is a settling chamber, and the second is a filter bed filled with sand or another filtering media. As storm water flows into the first chamber, large particles settle out, and then finer particles and other pollutants are removed as storm water flows through the filtering medium. There are several modifications of the basic sand filter design, including the surface sand filter, underground sand filter, perimeter sand filter, organic media filter, and Multi-Chamber Treatment Train. All of these filtering practices operate on the same basic principle. Modifications to the traditional surface sand filter were made primarily to fit sand filters into more challenging design sites (e.g., underground and perimeter filters) or to improve pollutant removal (e.g., organic media filter).

APPLICABILITY

Sand filters can be applied in most regions of the country and on most types of sites. Some restrictions at the site level, however, might restrict the use of sand filters as a storm water management practice (see Siting and Design Considerations).

Regional Applicability

Although sand filters can be used in both cold and arid climates, some design modifications might be necessary (see Siting and Design Considerations).

Ultra-Urban Areas

Ultra-urban areas are densely developed urban areas in which little pervious surface is present. Sand filters in general are good options in these areas because they consume little space. Underground and perimeter sand filters in particular are well suited to the ultra-urban setting because they consume no surface space.

Storm Water Hot Spots

Storm water hot spots are areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in storm water. These areas include commercial nurseries, auto recycle facilities, commercial parking lots, fueling stations, storage areas, industrial rooftops, marinas, outdoor container storage of liquids, outdoor loading/unloading facilities, public works storage areas, hazardous materials generators (if containers are exposed to rainfall), vehicle service and maintenance areas, and vehicle and equipment washing/steam cleaning facilities. Sand filters are an excellent option to treat runoff from storm water hot spots because storm water treated by sand filters has no interaction with, and thus no potential to contaminate, the groundwater.

Storm Water Retrofit

A storm water retrofit is a storm water management practice (usually structural) put into place after development has occurred to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. Sand filters are a good option to achieve water quality goals in retrofit studies where space is limited because they consume very little surface space and have few site restrictions. It is important to note, however, that sand filters cannot treat a very large drainage area. Using small-site BMPs in a retrofit may be the only option for a retrofit study in a highly urbanized area, but it is expensive to treat the drainage area of an entire watershed using many small-site practices, as opposed to one larger facility such as a pond.

Cold Water (Trout) Streams

Some species in cold water streams, notably trout, are extremely sensitive to changes in temperature. To protect these resources, designers should avoid treatment practices that increase the temperature of the storm water runoff they treat. Sand filters can be a good treatment option for cold water streams. In some storm water treatment practices, particularly wet ponds, runoff is warmed by the sun as it resides in the permanent pool. Surface sand filters are typically not designed with a permanent pool, although there is ponding in the sedimentation chamber and above the sand filter. Designers may consider shortening the detention time in cold water watersheds. Underground and perimeter sand filter designs have little potential for warming because these practices are not exposed to the sun.

DESIGN AND SITING

Siting and Design Considerations

In addition to the broad applicability issues described above, designers need to consider conditions at the site level and need to incorporate design features to improve the longevity and performance of the practice, while minimizing the maintenance burden.

Siting Considerations

Some considerations when selecting a storm water management practice are the drainage area the practice will need to treat, the slopes both at the location of the practice and draining to it, soil and subsurface conditions, and the depth of the seasonably high ground water table. Although sand filters are relatively versatile, some site restrictions such as available head might limit their use.

Drainage Area

Sand filters are best applied on relatively small sites (up to 10 acres for surface sand filters and closer to 2 acres for perimeter or underground filters [MDE, 2000]). Filters have been used on larger drainage areas, of up to 100 acres, but these systems can clog when they treat larger drainage areas unless adequate measures are provided to prevent clogging, such as a larger sedimentation chamber or more intensive regular maintenance.

Slope

Sand filters can be used on sites with slopes up to about 6 percent. It is challenging to use most sand filters in very flat terrain because they require a significant amount of elevation drop, or head (about 5 to 8 feet), to allow flow through the system. One exception is the perimeter sand filter, which can be applied with as little as 2 feet of head.

Soils/Topography

When sand filters are designed as a stand-alone practice, they can be used on almost any soil because they can be designed so that storm water never infiltrates into the soil or interacts with the ground water. Alternatively, sand filters can be designed as pretreatment for an infiltration practice, where soils do play a role.

Ground Water

Designers should provide at least 2 feet of separation between the bottom of the filter and the seasonally high ground water table. This design feature prevents both structural damage to the filter and possibly, though unlikely, groundwater contamination.

Design Considerations

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. Some features, however, should be incorporated into most designs. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

Pretreatment

Pretreatment is a critical component of any storm water management practice. In sand filters, pretreatment is achieved in the sedimentation chamber that precedes the filter bed. In this chamber, the coarsest particles settle out and thus do not reach the filter bed. Pretreatment reduces the maintenance burden of sand filters by reducing the potential of these sediments to clog the filter. Designers should provide at least 25 percent of the water quality volume in a dry or wet sedimentation chamber as pretreatment to the filter system. The water quality volume is the amount of runoff that will be treated for pollutant removal in the practice. Typical water quality volumes are the runoff from a 1-inch storm or ½ inch of runoff over the entire drainage area to the practice.

The area of the sedimentation chamber may be determined based on the Camp-Hazen equation, as adapted by the Washington State Department of Ecology (Washington State DOE, 1992). This equation can be expressed as:

$A_s = (Q_o/W)\,ln(1-E)$

where:

A_s = surface area (ft^2);
Q_o = discharge rate from basin (water quality volume/detention time);
W = particle settling velocity (ft/s);

[CWP (1996) used a settling of 0.0004 ft/s for drainage areas greater than 75% impervious and 0.0033 ft/s for drainage areas less than or equal to 75% impervious to account for the finer particles that erode from pervious surfaces.]

E = removal efficiency fraction (usually assumed to be about 0.9(90%)).

Using the simplifying assumption of a 24-hour detention time, CWP (1996) reduced the above equation to

$A_s = 0.066WTV$ (>75%)

$A_s = 0.0081WTV$ (< or = 75%)

where

WTV = water quality volume (ft^3), or the volume of storm water to be treated by the practice.

Treatment

Treatment design features help enhance the ability of a storm water management practice to remove pollutants. In filtering systems, designers should provide at least 75 percent of the water quality volume in the practice (including both the sand chamber and the sediment chamber). In sand filters, designers should select a medium sand as the filtering medium.

The filter bed should be sized using Darcy's Law, which relates the velocity of fluids to the hydraulic head and the coefficient of permeability of a medium. The resulting equation, as derived by the city of Austin, Texas, (1996), is

$AF = WTV\ d/[k\ t\ (h+d)]$

where

AF = area of the filter bed (ft^2);

d = depth of the filter bed (ft; usually about 1.5 feet, depending on the design);

k = coefficient of permeability of the filtering medium (ft/day);
t = time for the water quality volume to filter through the system (days; usually assumed to be 1.67 days); and
h = average water height above the sand bed (ft; assumed to be one-half of the maximum head).

Typical values for k, as assembled by CWP (1996), are shown in Table 1.

Table 1: Coefficient of permeability values for storm water filtering practices (CWP, 1996)

Filter Medium	Coefficient of Permeability (ft/day)
Sand	3.5
Peat/Sand	2.75
Compost	8.7

Conveyance

Conveyance of storm water runoff into and through a storm water practice is a critical component of any storm water management practice. Storm water should be conveyed to and from practices safely and in a manner that minimizes erosion potential. Ideally, some storm water treatment can be achieved during conveyance to and from the practice.

Typically, filtering practices are designed as "off-line" systems, meaning that they have the smaller water quality volume diverted to them only during larger storms, using a flow splitter, which is a structure that bypasses larger flows to the storm drain system or to a stabilized channel. One exception is the perimeter filter; in this design, all flows enter the system, but larger flows overflow to an outlet chamber and are not treated by the practice.

All filtering practices, with the exception of exfilter designs (see Design Variations) are designed with an under drain below the filtering bed. An under drain is a perforated pipe system in a gravel bed, installed on the bottom of filtering practices and used to collect and remove filtered runoff.

Maintenance Reduction

In addition to regular maintenance activities needed to maintain the function of storm water practices, some design features can be incorporated to ease the maintenance burden of each practice. Designers should provide maintenance access to filtering systems. In underground sand filters, confined space rules defined by the Occupational Safety and Health Administration (OSHA) need to be addressed.

Landscaping

Landscaping can add to both the aesthetic value and the treatment ability of storm water practices. In sand filters, little landscaping is generally used on the practice, although surface sand filters and organic media filters may be designed with a grass cover on the surface of the filter. In all filters, designers need to ensure that the contributing drainage has dense vegetation to reduce sediment loads to the practice.

Design Variations

As mentioned earlier in this fact sheet, there are five basic storm water filter designs--surface sand filter, underground filter, perimeter filter (also known as the "Delaware" filter), organic media filter, and Multi-Chamber Treatment Train. Other design variations can incorporate design features to recharge ground water or to meet the design challenges of cold or arid climates.

Underground Sand Filter

The underground sand filter is a modification of the surface sand filter, where all of the filter components are underground. Like the surface sand filter, this practice is an off-line system that receives only the smaller water quality events. Underground sand filters are expensive to construct but consume very little space. They are well suited to highly urbanized areas.

Multi-Chamber Treatment Train

The Multi-Chamber Treatment Train (Robertson et al., 1995) is essentially a "deluxe sand filter." This underground system consists of three chambers. Storm water enters into the first chamber, where screening occurs, trapping large sediments and releasing highly volatile materials. The second chamber provides settling of fine sediments and further removal of volatile compounds and also floatable hydrocarbons through the use of fine bubble diffusers and sorbent pads. The final chamber provides filtration by using a sand and peat mixed medium for reduction of the remaining pollutants. The top of the filter is covered by a filter fabric that evenly distributes the water volume and prevents channelization. Although this practice can achieve very high pollutant removal rates, it might be prohibitively expensive in many areas and has been implemented only on an experimental basis.

Exfiltration/Partial Exfiltration

In exfilter designs, all or part of the under drain system is replaced with an open bottom that allows infiltration to the ground water. When the under drain is present, it is used as an overflow device in case the filter becomes clogged. These designs are best applied in the same soils where infiltration practices are used (see Infiltration Basin and Infiltration Trench fact sheets).

Regional Variations

Arid Climates

Filters have not been widely used in arid climates. In these climates, however, it is probably necessary to increase storage in the sediment chamber to account for high sediment loads. Designers should consider increasing the volume of the sediment chamber to up to 40 percent of the water quality volume.

Cold Climates

In cold climates, filters can be used, but surface or perimeter filters will not be effective during the winter months, and unintended consequences might result from a frozen filter bed. Using alternative conveyance measures such as a weir system between the sediment chamber and filter bed may avoid freezing associated with the traditional standpipe. Where possible, the filter bed should be below the frost line. Some filters, such as the peat/sand filter, should be shut down during the winter. These media will become completely impervious during freezing conditions. Using a larger under drain system to encourage rapid draining during the winter months may prevent freezing of the filter bed. Finally, the sediment chamber should be larger in cold climates to account for road sanding (up to 40 percent of the water quality volume).

ADVANTAGES/LIMITATIONS

UNDERGROUND SAND FILTERS

Sand filters can be used in unique conditions where many other storm water management practices are inappropriate, such as in karst (i.e., limestone) topography or in highly urbanized settings. There are several limitations to these practices, however. Sand filters cannot control floods and generally are not designed to protect stream channels from erosion or to recharge the ground water. In addition, sand filters require frequent maintenance, and underground and perimeter versions of these practices are easily forgotten because they are out of sight. Perhaps one of the greatest limitations to sand filters is that they cannot be used to treat large drainage areas. Finally, surface sand filters are generally not aesthetically pleasing management practices. Underground and perimeter sand filters are not visible, and thus do not add or detract from the aesthetic value of a site.

MAINTENANCE

Intense and frequent maintenance and inspection practices are needed for filter systems. Table 2 outlines some of these requirements.

Table 2: Typical maintenance/inspection activities for filtration systems (Adapted from WMI, 1997; CWP, 1997)

Activity	Schedule
• Ensure that contributing area, filtering practice, inlets, and outlets are clear of debris. • Ensure that the contributing area is stabilized and mowed, with clippings removed. • Check to ensure that the filter surface is not clogging (also after moderate and major storms). • Ensure that activities in the drainage area minimize oil/grease and sediment entry to the system. • If a permanent pool is present, ensure that the chamber does not leak and that normal pool level is retained.	Monthly
• Replace sorbent pillows (Multi-Chamber Treatment Train only).	Biannual
• Check to see that the filter bed is clean of sediments, and the sediment chamber is no more than one-half full of sediment. Remove sediment if necessary. • Make sure that there is no evidence of deterioration, sailing, or cracking of concrete. • Inspect grates (if used). • Inspect inlets, outlets, and overflow spillway to ensure good condition and no evidence of erosion. • Repair or replace any damaged structural parts. • Stabilize any eroded areas. • Ensure that flow is not bypassing the facility. • Ensure that no noticeable odors are detected outside the facility.	Annual

EFFECTIVENESS

Structural storm water management practices can be used to achieve four broad resource protection goals: flood control, channel protection, ground water recharge, and pollutant removal. Filtering practices are for the most part adapted only to provide pollutant removal.

Ground Water Recharge

In exfilter designs, some ground water recharge can be provided; however, none of the other sand filter designs can provide recharge.

Pollutant Removal

Sand filters are effective storm water management practices for pollutant removal. Removal rates for all sand filters and organic filters are presented in Table 3. With the exception of nitrates, which appear to be exported from filtering systems, they perform relatively well at removing pollutants. The export of nitrates from filters may be caused by mineralization of organic nitrogen in the filter bed. Table 3 shows typical removal efficiencies for sand filters.

Table 3: Sand filter removal efficiencies (percent)

	Sand Filters (Schueler, 1997)	Peat/Sand Filter (Curran, 1996)	Compost Filter System		Multi-Chamber Treatment Train		
			Stewart, 1992	Leif, 1999	Pitt et al., 1997	Pitt, 1996	Greb et al., 1998
TSS	87	66	95	85	85	83	98
TP	51	51	41	4	80	-	84
TN	44	47	-	-	-	-	-
Nitrate	13	22	34	95	-	14	-
Metals	34-80	26-75	61-88	44-75	65-90	91-100	83-89
Bacteria	55	-	-	-	-	-	-

From the few studies available, it is difficult to determine if organic filters necessarily have higher removal efficiencies than sand filters. The Multi-Chamber Treatment Train appears to have high pollutant removal for some constituents, although these data are based on only a handful of studies. The siting and design criteria presented in this fact sheet reflect the best current information and experience to improve the performance of sand filters. A recent joint project of the American Society of Civil Engineers (ASCE) and the U.S. EPA Office of Water may help to isolate specific design features that can improve performance. The National Stormwater Best Management Practice (BMP) database is a compilation of storm water practices that includes both design information and performance data for various practices. As the database expands, inferences about the extent to which specific design criteria influence pollutant removal may be made. For more information on this database, access the BMP database web page at *http://www.bmpdatabase.org*.

COST

There are few consistent data on the cost of sand filters, largely because, with the exception of Austin, Texas, Alexandria, Virginia, and Washington, D.C., they have not been widely used. Furthermore, filters have such varied designs that it is difficult to assign a cost to filters in general. A study by Brown and Schueler (1997) was unable to find a statistically valid relationship between the volume of water treated in a filter and the cost of the practice, but typical total cost of installation ranged between $2.50 and $7.50 per cubic foot of storm water treated, with an average cost of about $5 per cubic foot. (This estimate includes approximately 25 percent contingency costs beyond the construction costs reported). The cost per impervious acre treated varies considerably depending on the region and design used (see Table 4). It is important to note that, although underground and perimeter sand filters can be more expensive than surface sand filters, they consume no surface space, making them a relatively cost-effective practice in ultra-urban areas where land is at a premium.

Table 4: Construction costs for various sand filters (Source: Schueler, 1994)

Region (Design)	Cost/Impervious Acre
Delaware (Perimeter)	$10,000
Alexandria, VA (Perimeter)	$23,500
Austin, TX (<2 acres) (Surface)	$16,000
Austin, TX (>5 acres) (Surface)	$3,400
Washington, DC (underground)	$14,000
Denver, CO	$30,000–$50,000
Multi-Chamber Treatment Train	$40,000–$80,000

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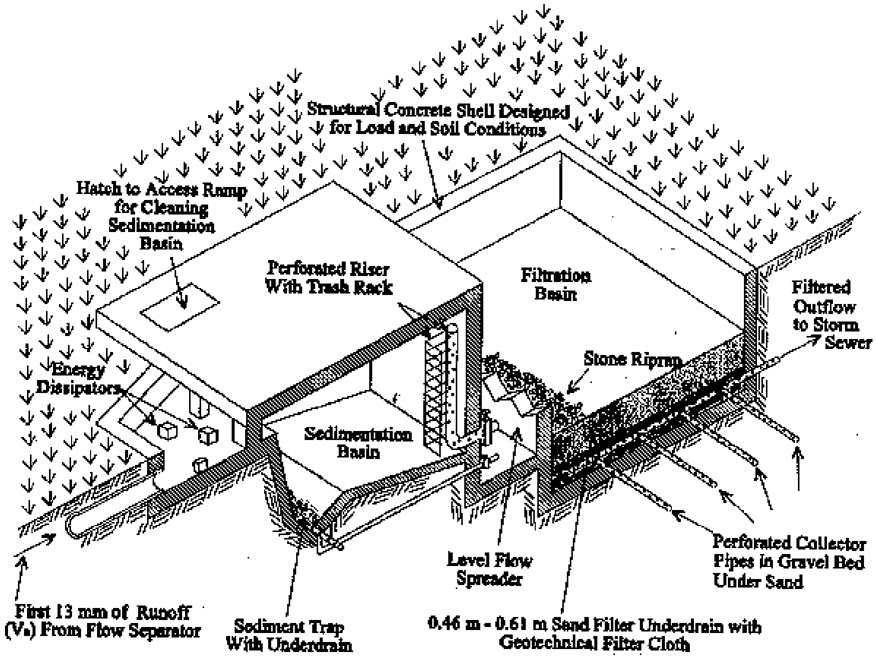
BMP FACTSHEET
SURFACE SAND FILTERS

SURFACE SAND FILTERS



Source: Austin sand filter with full sedimentation protection (Young et al., 1996)

Water Quantity Benefits (low, medium, high)	
Rate Reduction	**Medium**
Volume Reduction	**Low**

Water Quality Benefits (% Reduction)	
Total Suspended Solids (TSS)	**75-92**
Total Phosphorus (P)	**27-80**
Total Nitrogen (N)	**27-71**
Metals	**33-91**
Oil and Grease	**NA**
Bacteria	**NA**

Other Considerations (low, medium, high or other)	
Area Typically Served (acres)	**2-5**
% of Area Needed for BMP	**2-3**
Capital Costs	**Medium**
O& M Costs	**Medium**
Maintenance	**Medium**
Training	**Low**
Effective Life (years)	**5-20**

DESCRIPTION

The surface sand filter has been employed since the early 1980s to provide stormwater quality management. One of the forerunners in developing the surface sand filter design has been the City of Austin, Texas. The Austin design consists of a bypass chamber, a sedimentation chamber that provides pretreatment, a flow distribution cell, and a sand filter bed. The design illustrated shows many of the features common to surface sand filters. Typically, the filter bed has a 450 to 600 mm (18 to 24 in) deep sand layer that traps or strains pollutants before runoff is collected in an underdrain system (gravel and perforated pipe) and conveyed to a discharge point.

A bypass chamber is used to protect the BMP from high inflows, diverting any flow in excess of the capacity of the structure. This works with the sedimentation cell(s) to prevent high loads of coarse sediment from entering the filter bed. In terms of drainage area, the Austin design has been successfully employed for drainage areas ranging from 0.4 to 40.5 ha (1 to 100 ac).

Surface sand filters are very well suited to managing the first flush volume, which typically contains the highest concentration of pollutants. However, the design is poorly suited to providing stormwater quantity management to prevent flooding because high flows can easily damage the filter bed. As a result, it is strongly recommended that the design be installed in an off-line configuration.

The Austin filter works by a combination of sedimentation, filtration, and adsorption. The sedimentation section located just upstream of the filter section serves as pretreatment, removing larger-diameter suspended solids. Partially treated stormwater then flows slowly into the filter section, where fine-grain material is strained from the stormwater as it passes through the filter medium. The sand medium filter traps up to 90 percent of the small particles in stormwater runoff (6 to 41 microns) if a 460 mm (18 in) layer of sand is used. However, the extent of adsorption by sand of some dissolved pollutants is relatively small when compared to other filter media. For example, sand medium adsorbs much less positively charged dissolved metals and hydrocarbons than either soil or peat medium primarily due to its relatively low cation exchange capacity (CEC); sand has a CEC that is 13 percent that of the soil medium and 0.002 percent of the peat medium.

APPLICABILITY

Although it has been applied within an urban setting, the Austin sand filter may require a significant commitment of land area (generally between two and seven percent of the drainage area). Consequently, many of the installations within the City of Austin are in newer, less densely developed portions of the municipality. Within an ultra-urban setting this design might be restrictive requiring a completely subsurface BMP (see Underground Sand Filter Fact Sheet).

The applicability of surface sand filters to roadway projects has been demonstrated. For example, the Texas Department of Transportation has designed and/or installed Austin sand filters to provide stormwater management for several large highway projects. Overall, the design provides dependable performance and can be designed so it does not pose an additional safety hazard for automotive traffic.

ADVANTAGES/LIMITATIONS

Surface sand filters can often require large land area and is not very effective at dissolved pollutants. Surface sand filters are only useful for water quality control and not water quantity control.

DESIGN & SIZING

Various design approaches can be taken in designing surface sand filters, including those developed in Austin. Design differences tend to be found in the size of the sedimentation area, the duration of sedimentation, and the loading rate of the filter media. For practicality, most designs limit the maximum water depth in the facility to less than 2.4 m (8 ft) and drain the system by gravity.

There are two basic designs for the Austin surface sand filter that manage the first 12.7 mm (0.5 in) of runoff, a partial sedimentation design and a full sedimentation design. The designs differ in terms of the volume of the sedimentation chamber and the size of the filter area. A partial sedimentation design creates a smaller footprint than a full sedimentation design but typically requires more maintenance. The partial sedimentation design is intended for areas that are relatively flat sloped and requires sufficient sedimentation area to store 20 percent of the water quality volume. The partial sedimentation design requires 16.7 m2 (180 ft2) of filter area per impervious acre. The full sedimentation design provides sufficient sedimentation area to store the entire water quality volume (100 percent), a volume that is subsequently released to the filter bed over a 24-hour period. The full sedimentation design requires 9.3 m2 (100 ft2) of area per impervious acre (assuming a permeability of the sand medium of 1 m/day [3.5 ft/day]). More extensive information regarding the design process used for the Austin sand filter should be acquired directly from the City of Austin's Environmental Criteria Manual (City of Austin, 1991).

There are also other approaches to surface sand filter designs that can be considered. One general rule of thumb is the required sedimentation area in square meters should be equal to 0.020 times the water quality volume in cubic meters (0.066 for area in square feet and volume in cubic feet) for drainage areas with an imperviousness of less than 75 percent (Claytor and Schueler, 1996). For areas with imperviousness greater than 75 percent, the sedimentation area commitment is 0.0024 times the water quality volume (0.0081 for area in square feet and volume in cubic feet). These recommendations recognize that ultra-urban runoff typically contains a high percentage of large-diameter sediment particles and therefore the settling area can be decreased (Shaver, 1994). When using this design approach, the recommended length-to-width ratio of the settling chamber is 2:1 or greater to limit short-circuiting, and the minimum recommended water depth in the settling chamber is 0.92 m (3 ft). This design approach also calls for the total storage volume in the sedimentation chamber and filter chamber to be equal to 75 percent of the water quality volume. At least half of the total storage volume should be located in the sedimentation chamber. The facility storage volume calculation should include void storage in the sand medium (typical porosity between 30 and 40 percent). In sizing the filter area it is recommended that a drawdown time of 40 hours be used and that the total depth of sand medium not exceed 0.61 m (2 ft). More information regarding this design approach can be found in Design of Stormwater Filtering Systems (Claytor and Schueler, 1996).

It should be noted that for any of the surface filter designs it is possible to substitute filter media other than sand. Refer to the Organic Media Filters Fact Sheet for additional information on organic media filters (peat/sand and compost media) and their advantages and disadvantages. Although over 500 Austin sand filters are currently operating, it is not known how long the basic design will last. Given the relatively low level technology typically employed, it seems reasonable to assume an effective life between 25 and 50 years with regular maintenance.

MAINTENANCE

In general, the recommended frequency for performance monitoring is at least once per year. Each inspection should log information on the depth and location of any ponding, the depth of discoloration in the filter bed, and the depth of accumulated material over the sand media.

Most filters exhibit diminished capacity after a few years due to surface clogging by organic matter, fine silts, and hydrocarbons. Restoration of the original filtration capacity includes manual removal of any accumulated material and the first several inches of discolored sand. New sand is placed to reestablish the design grade of the filter medium. From a review of numerous references, it appears the material (sand/silt) accumulates in most sand filters at a rate between 13 to 25 mm/yr (0.5 to 1 in/yr). Maintenance can be reduced by employing surface sand filters only in drainage areas with 100 percent imperviousness. This significantly reduces the fine-grain material reaching the filter (silt and clay) which can clog the filter bed (Schueler, 1995). In areas with high trash loading, a wide-mesh geotextile screen can be placed over portions of the filter surface to simplify removal of the debris.

Regarding specific maintenance issues for the Austin sand filter design, the partial sedimentation design requires more frequent maintenance of the filter bed because there is less settling of solids in the sedimentation chamber. This tends to lead to greater sediment loads entering the filter bed than is experienced for full sedimentation designs (Young et al., 1996). Greater sediment loads translate into higher maintenance costs because more frequent replacement of the sand media will be required.

EFFECTIVENESS

The Austin sand filter design has demonstrated good total suspended solids (TSS) removals, typically providing 85 percent treatment. Performance for nutrients is less significant, and in fact the sand filter may be a source of nitrate (NO_3) since ammonia in stormwater will undergo nitrification in the aerobic filter. However, sand filters are reported to decrease the total nitrogen (TN) load by approximately 35 percent. Total phosphorus (TP) removals range up to 55 percent, and there is a wide variation in metal removal rates (ranging between 35 and 90 percent). Removal of oil and grease by sand filters has been reported to average between 55 and 84 percent (Horner and Horner, 1995). Reduction in fecal coliform bacteria ranges between 40 and 80 percent.

The bulk of Austin sand filter designs have been in a warmer climate (central Texas) and reported removal rates probably reflect this influence (see Table 13). The filter performance would probably decrease if exposed to prolonged cold periods, which freeze the filter media. However, in a recent application of a sand filter in Alexandria, Virginia, it was reported that the filter operated effectively immediately after an arctic freeze even with several inches of frozen runoff in the settling area (Bell et al., 1995).

With the integration of a sedimentation chamber, the design provides pretreatment for the filter. However, where high loadings of oil or grease are encountered, additional pretreatment measures, such as grassed swales or vegetated filter strips are advisable.

COST

The surface sand filter design is a moderately expensive BMP to employ (Claytor and Schueler, 1996). However, the cost of installation is strongly correlated with the nature of the construction employed. If the filter is installed within an ultra-urban setting, it is likely that relatively expensive concrete walls will be used to create the various chambers. This type of installation will be significantly more expensive than an earthen-walled design, where relatively inexpensive excavation and compaction construction techniques lower the installation cost. However, earthen-wall designs require a greater land area commitment, which can offset the reduction in construction costs.

The construction cost of surface sand filters is also related to economies of scale-the cost per impervious hectare or acre served decreases with an increase in the service area. In 1994, the construction costs for Austin sand filters were $39,500 per impervious hectare (or $16,000 per impervious acre) for facilities serving less than two acres and $8,400 per impervious hectare (or $3,400 per impervious acre) for facilities serving greater than five acres (Schueler, 1994). These construction cost estimates exclude real estate, design, and contingency costs. (Note that these unit cost values should be used for conceptual cost estimating purposes only.)

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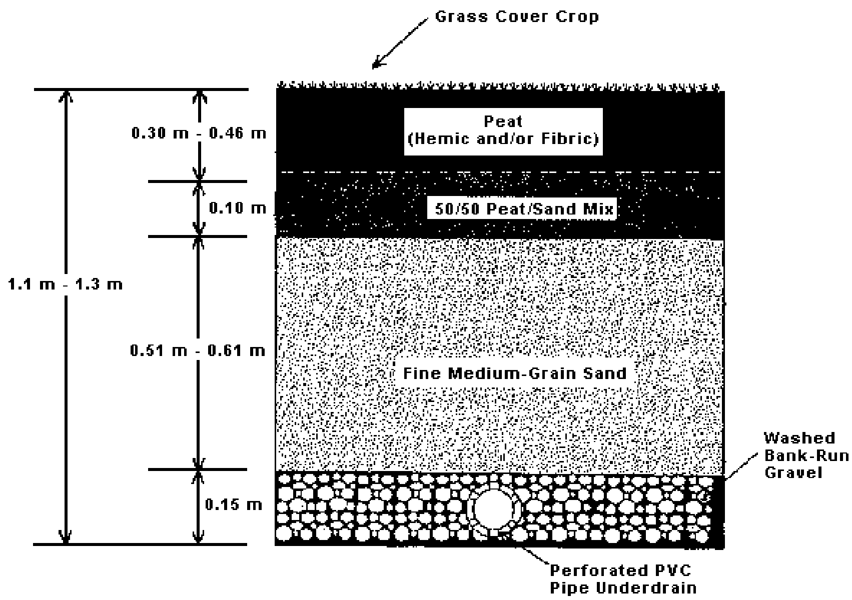
BMP FACTSHEET
ORGANIC MEDIA FILTERS

ORGANIC MEDIA FILTERS



Source: Typical peat-sand filter cross section (Young et al., 1996)

Water Quantity Benefits (low, medium, high)	
Rate Reduction	**Medium**
Volume Reduction	**Low**

Water Quality Benefits (% Reduction)	
Total Suspended Solids (TSS)	**90-95**
Total Phosphorus (P)	**49**
Total Nitrogen (N)	**55**
Metals	**48-90**
Oil and Grease	**90**
Bacteria	**90**

Other Considerations (low, medium, high or other)	
Area Typically Served (acres)	**2-5**
% of Area Needed for BMP	**2-3**
Capital Costs	**Medium**
O& M Costs	**High**
Maintenance	**Medium**
Training	**Low**
Effective Life (years)	**5-20**

DESCRIPTION

The organic media filters improve water quality through a combination of sedimentation, filtration, and adsorption processes. The sedimentation section located just upstream of the filter section serves as pretreatment, removing larger diameter suspended solids and capturing floating hydrocarbons. Partially treated stormwater then flows slowly into the filter section where fine-grain material is strained from stormwater as it passes through the filter media.

The subsurface or underground filter design is well adapted for applications with limited land area and provides turnkey performance that is independent of local soil conditions, groundwater levels, and other factors. The underground filter design typically consists of a multi-chamber vault that is completely below grade and is covered with a grating or structural concrete. It is most useful for multipurpose land uses, that is, where committed land area will also be used for automobile parking or for public parks. The surface filter design, sometimes called the Austin filter, also consists of a multichambered facility. While most of the filter is located at or slightly below grade the filter is not covered and so requires a commitment of land area (refer to the Fact Sheets on Underground Sand Filters and Surface Sand Filters for additional information).

As with other stormwater filters, the purpose of organic media filters is to manage the first flush, which typically contains the highest concentration of pollutants. If designed as an off-line facility, however, such filters can provide true capture and treatment of any water quality volume.

A number of design variations or proprietary systems featuring organic media are currently available (e.g., StormFilter™). While these systems basically use the same treatment mechanisms, there are differences in the size of settling areas or chambers, loading rates, and media configuration.

ORGANIC MEDIA FILTERS

APPLICABILITY

Organic media filters can be used in underground and surface filter designs. Of these, the underground filter is considered to be more applicable to the ultra-urban setting. It requires a small commitment of land area, provides dependable service, and is relatively effective in removing urban pollutants. Furthermore, its design is inherently flexible, and the size and shape of the unit can be set based on local requirements.

Surface filter designs can also utilize organic media and are typically less expensive to construct and maintain than underground filter designs. Unfortunately, surface designs typically prevent multipurpose land uses and therefore are limited in their application to ultra-urban settings. In roadside settings where there is sufficient space (typically two to three percent of the drainage area served), a surface filter design may be preferred.

If they are placed below the frost line, the performance of organic media filters is relatively independent of season. In addition, the level of treatment is generally independent of placement and in situ soil conditions do not affect performance. For most designs pretreatment is integrated into the filter facility in the form of a settling chamber. Additional pretreatment may be provided by streetsweeping to remove accumulated sand and trash, which can diminish the useful life of the filter.

ADVANTAGES/LIMITATIONS

Organic media filters can be adapted to a variety of sites as above or below ground using a relatively small area.

Organic media filters, similar to sand filters, are normally only designed for water quality improvement and not water quantity control.

DESIGN & SIZING

Two broad categories of organic media designs exist: (1) variations on existing sand medium filter designs and (2) proprietary designs that are optimized for organic media. For the first design category, organic media are simply substituted for sand, affecting the size of the filter portion of the facility. Information on existing sand filter designs is provided in the Surface Sand Filters and Underground Sand Filters Fact Sheets. These sand medium designs should be varied to reflect the permeability of the substituted organic media. It has been recommended in a recent evaluation that combination peat/sand filters be designed based on a permeability of 0.8 m/day (2.75 ft/day), or a value approximately 79 percent of that recommended for sand-only filters (City of Austin, 1991). On the other hand, compost medium filters have a wide range of permeability values depending on their age and degree of clogging. Designers should be aware that initial permeability can be very high (in the range of 122 m/day [400 ft/day], a value much higher than that used to specify the filter area); Claytor and Schueler (1996) recommend a design permeability value of 2.7 m/day (8.7 ft/day). Several good sources are available for detailed design procedures and information on underground and surface filter designs, including Design of Stormwater Filtering Systems (Claytor and Schueler, 1996) and Evaluation and Management of Highway Runoff Water Quality (Young et al., 1996).

One proprietary underground design that features organic media is the CSF® Type II system, which uses cylindrical filter cartridges filled with a granular organic medium consisting of composted leaves. (Figure 16 illustrates a recent advancement in StormFilter™ technology, formerly the CSF® system.) The filter works by percolating stormwater through the cylindrical cartridges containing certified CSF® compost media. Because of the highly porous nature of the granular media, the flow through a newly installed cartridge is restricted by a valve to 57 L/min (15 gal/min). This allows more time for sediment to settle and ensures adequate contact time for pollutant removal. The CSF® system is equipped with scum baffles that trap floating debris and surface films; even during overflow conditions. A typical unit requires 0.67 m (2.2 ft) of drop from the inlet invert to the outlet invert. A portion of the sediment settles out in the area around the cylinders; more sediment, including particulate forms of nutrients and heavy metals, are trapped by the porous structure of the compost. Sizes range from 1.83 m X 2.44 m (6 ft X 8 ft) (treating about 284 L/min [75 gal/min] peak flow) to 2.44 m X 5.49 m (8 ft X 18 ft) vaults (which treat about 1360 L/min [360 gal/min], or 0.023 m3/s [0.8 ft3/s]). Housed in standard size precast or cast in place concrete vaults, the filter systems are installed in-line with storm drains.

MAINTENANCE

Annual maintenance costs for organic filters vary as a function of the design used. Surface filter designs using a peat/sand medium require periodic mowing and removal of the grass cuttings to avoid unwanted plant growth. In addition, at least an annual inspection is required for this design and reseeding of the grass cover crop may be required.

Filter designs that feature horizontal compost bed filters will likely be replaced every three to four years to prevent heavy metal concentrations from reaching levels that exceed the "clean sludge" definition under 40 CFR Part 503 (USEPA, 1994). These designs also require removal of accumulated material and rototilling of the compost to reestablish the required permeability.

Maintenance for underground designs that use organic media can be inferred from information given for sand-only medium filters given in the Fact Sheets for Underground Sand Filters and Surface Sand Filters. A D.C. underground sand filter serving a 0.4 ha (1 ac) area was serviced by removal and replacement of a gravel ballast and filter cloth, for $1300 in 1994 (Bell, 1996). It is reasonable to assume organic media filters would require comparable service. It should be noted that repair of subsurface filters requires confined space entry, which dictates larger management crews and a higher cost to repair than surface filters.

The maintenance of proprietary organic media filters varies with the manufacturer; it is likely that maintenance will include removing accumulated material that has settled in the facility and periodic replacement of organic media cartridges on an annual or biennial basis. For example, manufacturers of the CSF® system indicate annual maintenance costs will range from $500 to $1200 (for 280 and 1360 L/min [75 and 360 gal/min] systems, respectively).

EFFECTIVENESS

Organic media filters are highly efficient in removing fine-grain material (small particles in stormwater runoff between 6 and 41 microns). As an additional benefit, organic media are capable of removing a portion of dissolved material found in stormwater. For example, the peat medium has a cation exchange capacity (CEC) 500 times that of sand. This greatly increases its ability to adsorb or capture positively charged dissolved metals and hydrocarbons, increasing the removal performance.

Organic media filters have demonstrated good total suspended solids (TSS) removals, typically providing 90 to 95 percent removal (Claytor and Schueler, 1996; Stewart, 1992). Performance for nutrients is less significant; in fact, the organic media may be a source of soluble phosphorus and nitrate (NO3). Total phosphorus (TP) removals range up to 49 percent, while variable removal of metals is typically between 48 and 90 percent (Figure 14). Removal of oil and gasoline averages about 90 percent (Claytor and Schueler, 1996).

COST

The cost of surface facilities using organic media filters is comparable to the cost of filtration facilities that use sand medium (with the exception of proprietary systems). For conceptual costing a price of $8,400 to $39,500 per impervious hectare served (or $3,400 to $16,000 per impervious acre served) can be used to estimate the construction cost of a proposed facility, excluding real estate, design, and contingency costs (Schueler, 1994).

Underground filters are generally considered to be a high-cost BMP option for water quality management. The construction cost per hectare served is typically around $34,600 and the cost per acre served is typically around $14,000, excluding real estate, design, and contingency costs (Schueler, 1994).

Drop-in CSF® vertical organic media units are typically precast vaults delivered to the site either partially or fully assembled. Typical cost variables include the need for ballast, type of lids and doors, customized casting of sections or holes, and depth of the vault. Systems treating peak flows of 280 and 1360 L/min (75 and 360 gal/min) have an estimated installed cost of $10,000 and $25,000, respectively (Stormwater Management, 1996).

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BMP FACTSHEET
BIORETENTION

BIORETENTION

Source: Symbiont

Water Quantity Benefits (low, medium, high)	
Rate Reduction	High
Volume Reduction	Medium
Water Quality Benefits (% Reduction)	
Total Suspended Solids (TSS)	75
Total Phosphorus (P)	50
Total Nitrogen (N)	50
Metals	75-80
Oils & Grease	NA
Bacteria	NA
Other Considerations (low, medium, high or other)	
Area Typically Served (acres)	1-50
% of Area Needed for BMP	4-10
Capital Costs	Medium
O&M Costs	Low
Maintenance	Medium
Training	Low
Effective Life (years)	5-20

DESCRIPTION

Bioretention areas are landscaping features adapted to provide on-site treatment of storm water runoff. They are commonly located in parking lot islands or within small pockets of residential land uses. Surface runoff is directed into shallow, landscaped depressions. These depressions are designed to incorporate many of the pollutant removal mechanisms that operate in forested ecosystems. During storms, runoff ponds above the mulch and soil in the system. Runoff from larger storms is generally diverted past the facility to the storm drain system. The remaining runoff filters through the mulch and prepared soil mix. Typically, the filtered runoff is collected in a perforated underdrain and returned to the storm drain system.

APPLICABILITY

Bioretention systems are generally applied to small sites and in a highly urbanized setting. Bioretention can be applied in many climatological and geologic situations, with some minor design modifications.

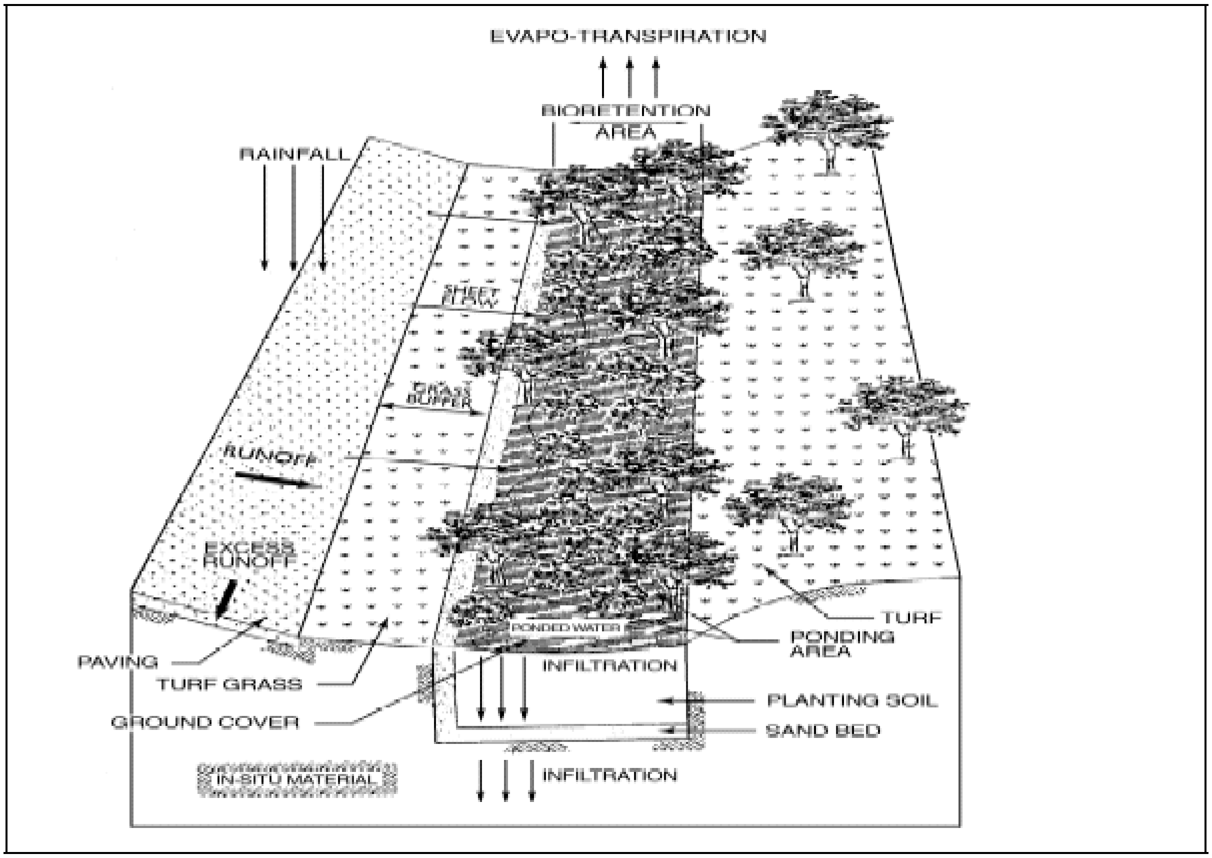
Regional Applicability

Bioretention systems are applicable almost everywhere in the United States. In arid or cold climates, however, some minor design modifications may be needed.

Ultra-Urban Areas

Ultra-urban areas are densely developed urban areas in which little pervious surface exists. Bioretention facilities are ideally suited to many ultra-urban areas, such as parking lots. While they consume a fairly large amount of space (approximately 5 percent of the area that drains to them), they can be fit into existing parking lot islands or other landscaped areas.

BIORETENTION



Bioretention Area
Source: ETA and Biohabitats, 1993

Storm Water Hot Spots

Storm water hot spots are areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in storm water. A typical example is a gas station or convenience store parking lot. Bioretention areas can be used to treat storm water hot spots as long as an impermeable liner is used at the bottom of the filter bed.

Storm Water Retrofit

A storm water retrofit is a storm water management practice (usually structural) put into place after development has occurred, to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. Bioretention can be used as a storm water retrofit, by modifying existing landscaped areas, or if a parking lot is being resurfaced. In highly urbanized areas, this is one of the few retrofit options that can be employed. However, it is very expensive to retrofit an entire watershed or subwatershed using storm water management practices designed to treat small sites.

Cold Water (Trout) Streams

Some species in cold water streams, notably trout, are extremely sensitive to changes in temperature. In order to protect these resources, designers should avoid treatment practices that increase the temperature of the storm water runoff they treat. Bioretention is a good option in cold water streams because water ponds in them for only a short time, decreasing the potential for stream warming.

ADVANTAGES/LIMITATIONS

Bioretention areas have a few limitations. Bioretention areas cannot be used to treat a large drainage area, limiting their usefulness for some sites. In addition, although the practice does not consume a large amount of space, incorporating bioretention into a parking lot design may reduce the number of parking spaces available. Finally, the construction cost of bioretention areas is relatively high compared with many other management practices (see Cost Considerations).

DESIGN AND SITING

In addition to the broad applicability concerns described above, designers need to consider conditions at the site level. In addition, they need to incorporate design features to improve the longevity and performance of the practice, while minimizing the maintenance burden.

Siting

Some considerations for selecting a storm water management practice are the drainage area the practice will need to treat, the slopes both at the location of the practice and the drainage area, soil and subsurface conditions, and the depth of the seasonably high ground water table. Bioretention can be applied on many sites, with its primary restriction being the need to apply the practice on small sites.

Drainage Area

Bioretention areas should usually be used on small sites (i.e., 5 acres or less). When used to treat larger areas, they tend to clog. In addition, it is difficult to convey flow from a large area to a bioretention area.

Slope

Bioretention areas are best applied to relatively shallow slopes (usually about 5 percent). However, sufficient slope is needed at the site to ensure that water that enters the bioretention area can be connected with the storm drain system. These storm water management practices are most often applied to parking lots or residential landscaped areas, which generally have shallow slopes.

Soils/Topography

Bioretention areas can be applied in almost any soils or topography, since runoff percolates through a man-made soil bed and is returned to the storm water system.

Ground Water

Bioretention should be separated somewhat from the ground water to ensure that the ground water table never intersects with the bed of the bioretention facility. This design consideration prevents possible ground water contamination.

Design Considerations

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. There are some features, however, that should be incorporated into most bioretention area designs. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

Pretreatment

Pretreatment refers to features of a management practice that cause coarse sediment particles and their associated pollutants to settle. Incorporating pretreatment helps to reduce the maintenance burden of bioretention and reduces the likelihood that the soil bed will clog over time. Several different mechanisms can be used to provide pretreatment in bioretention facilities. Often, runoff is directed to a grass channel or filter strip to filter out coarse materials before the runoff flows into the filter bed of the bioretention area. Other features may include a pea gravel diaphragm, which acts to spread flow evenly and drop out larger particles.

Treatment

Treatment design features help enhance the ability of a storm water management practice to remove pollutants. Several basic features should be incorporated into bioretention designs to enhance their pollutant removal. The bioretention system should be sized between 5 and 10 percent of the impervious area draining to it. The practice should be designed with a soil bed that is a sand/soil matrix, with a mulch layer above the soil bed. The bioretention area should be designed to pond a small amount of water (6–9 inches) above the filter bed.

Conveyance

Conveyance of storm water runoff into and through a storm water practice is a critical component of any storm water management practice. Storm water should be conveyed to and from practices safely and to minimize erosion potential. Ideally, some storm water treatment can be achieved during conveyance to and from the practice.

Bioretention practices are designed with an underdrain system to collect filtered runoff at the bottom of the filter bed and direct it to the storm drain system. An underdrain is a perforated pipe system in a gravel bed, installed on the bottom of the filter bed. Designers should provide an overflow structure to convey flow from storms that are not treated by the bioretention facility to the storm drain.

Maintenance Reduction

In addition to regular maintenance activities needed to maintain the function of storm water practices, some design features can be incorporated to reduce the required maintenance of a practice. Designers should ensure that the bioretention area is easily accessible for maintenance.

Landscaping

Landscaping is critical to the function and aesthetic value of bioretention areas. It is preferable to plant the area with native vegetation, or plants that provide habitat value, where possible. Another important design feature is to select species that can withstand the hydrologic regime they will experience. At the bottom of the bioretention facility, plants that tolerate both wet and dry conditions are preferable. At the edges, which will remain primarily dry, upland species will be the most resilient. Finally, it is best to select a combination of trees, shrubs, and herbaceous materials.

Design Variations

One design alternative to the traditional bioretention practice is the use of a "partial exfiltration" system, used to promote ground water recharge. Other design modifications may make this practice more effective in arid or cold climates.

Partial Exfiltration

In one design variation of the bioretention system, the underdrain is only installed on part of the bottom of the bioretention system. This design alternative allows for some infiltration, with the underdrain acting as more of an overflow. This system can be applied only when the soils and other characteristics are appropriate for infiltration (see Infiltration Trench and Infiltration Basin).

Arid Climates

In arid climates, bioretention areas should be landscaped with drought-tolerant species.

Cold Climates

In cold climates, bioretention areas can be used as snow storage areas. If used for this purpose, or if used to treat runoff from a parking lot where salt is used as a deicer, the bioretention area should be planted with salt-tolerant, nonwoody plant species.

MAINTENANCE

Bioretention requires frequent landscaping maintenance, including measures to ensure that the area is functioning properly, as well as maintenance of the landscaping on the practice. In many cases, bioretention areas initially require intense maintenance, but less maintenance is needed over time. In many cases, maintenance tasks can be completed by a landscaping contractor, who may already be hired at the site.

Table 1. Typical maintenance activities for bioretention areas (Source: ETA and Biohabitats, 1993)

Activity	Schedule
• Remulch void areas • Treat diseased trees and shrubs • Mow turf areas	As needed
• Water plants daily for 2 weeks	At project completion
• Inspect soil and repair eroded areas • Remove litter and debris	Monthly
• Remove and replace dead and diseased vegetation	Twice per year
• Add mulch • Replace tree stakes and wires	Once per year

EFFECTIVENESS

Structural storm water management practices can be used to achieve four broad resource protection goals. These include flood control, channel protection, ground water recharge, and pollutant removal. In general, bioretention areas can provide only pollutant removal.

Flood Control

Bioretention areas are not designed to provide flood control. These larger flows must be diverted to a detention pond that can provide flood peak reduction.

Channel Protection

Bioretention areas are generally not designed to provide channel protection because at the scale at which they are typically installed they are not able to infiltrate large volumes. (They are typically designed to treat and infiltrate the first inch of runoff and are bypassed by larger flows that can erode channels.) Channel protection must be provided by other means, such as ponds or other volume control practices.

Ground Water Recharge

Bioretention areas do not usually recharge the ground water, except in the case of the partial exfiltration design (see Design Variations).

Pollutant Removal

Little pollutant removal data have been collected on the pollutant removal effectiveness of bioretention areas. A field and laboratory analysis of bioretention facilities conducted by Davis et al. (1997), showed very high removal rates (roughly 95 percent for copper, 98 percent for phosphorus, 20 percent for nitrate, and 50 percent for total Kjeldhal nitrogen (TKN). Table 2 shows data from two other studies of field bioretention sites in Maryland.

Table 2. Pollutant removal effectiveness of two bioretention areas in Maryland (USEPA, 2000).

Pollutant	**Pollutant Removal**
Copper	43%–97%
Lead	70%–95%
Zinc	64%–95%
Phosphorus	65%–87%
TKN	52–67%
NH_4^+	92%
NO_3^-	15%–16%
Total nitrogen (TN)	49%
Calcium	27%

Assuming that bioretention systems behave similarly to swales, their removal rates are relatively high. The negative removal rate for bacteria may reflect sampling errors, such as failure to account for bacterial sources in the practice. Alternatively, these data may be the result of bacteria reproduction in the moist soils of swale systems.

There is considerable variability in the effectiveness of bioretention areas, and it is believed that properly designing and maintaining these areas may help to improve their performance. The siting and design criteria presented in this sheet reflect the best current information and experience to improve the performance of bioretention areas. A recent joint project of the American Society of Civil Engineers (ASCE) and the EPA Office of Water may help to isolate specific design features that can improve performance. The National Stormwater Best Management Practice (BMP) database is a compilation of storm water practices which includes both design information and performance data for various practices. As the database expands, inferences about the extent to which specific design criteria influence pollutant removal might be made. More information on this database is accessible on the BMP database web page at http://www.bmpdatabase.org.

COST

Bioretention areas are relatively expensive. A recent study (Brown and Schueler, 1997) estimated the cost of a variety of storm water management practices. The study resulted in the following cost equation for bioretention areas, adjusting for inflation:

$C = 7.30\ V^{0.99}$

where:

C = Construction, design, and permitting cost ($); and

V = Volume of water treated by the facility (ft^3).

An important consideration when evaluating the costs of bioretention is that this practice replaces an area that most likely would have been landscaped. Thus, the true cost of the practice is less than the construction cost reported. Similarly, maintenance activities conducted on bioretention areas are not very different from maintenance of a landscaped area. The land consumed by bioretention areas is relatively high compared with other practices (about 5 percent of the drainage area). Again, this area should not necessarily be considered lost, since the practice may only be slightly larger than a traditional landscaped area. Finally, bioretention areas can improve upon existing landscaping and can therefore be an aesthetic benefit.

REFERENCES

This fact sheet is copied from the United States Environmental Protection Agency Post Construction Stormwater Management in New Development & Redevelopment BMP Fact Sheet for Bioretention (cfpub.epa.gov/npdes/stormwater/menuofbmps/post_4.cfm).

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BMP FACTSHEET
VEGETATED FILTER STRIPS

AUBURN, INDIANA STORM WATER BMP TECHNICAL MANUAL

VEGETATED FILTER STRIPS

Source: Army Corps of Engineers

Water Quantity Benefits (low, medium, high)	
Rate Reduction	**Low**
Volume Reduction	**Low**

Water Quality Benefits (% Reduction)	
Total Suspended Solids (TSS)	**27-70**
Total Phosphorus (P)	**20-40**
Total Nitrogen (N)	**20-40**
Metals	**NA**
Oil and Grease	**NA**
Bacteria	**NA**

Other Considerations (low, medium, high or other)	
Area Typically Served (acres)	**<5**
% of Area Needed for BMP	**25**
Capital Costs	**Low**
O& M Costs	**Low**
Maintenance	**Medium**
Training	**Low**
Effective Life (years)	**20-50**

DESCRIPTION

Grassed filter strips (vegetated filter strips, filter strips, and grassed filters) are vegetated surfaces that are designed to treat sheet flow from adjacent surfaces. Filter strips function by slowing runoff velocities and filtering out sediment and other pollutants, and by providing some infiltration into underlying soils. Filter strips were originally used as an agricultural treatment practice, and have more recently evolved into an urban practice. With proper design and maintenance, filter strips can provide relatively high pollutant removal. One challenge associated with filter strips, however, is that it is difficult to maintain sheet flow, so the practice may be "short circuited" by concentrated flows, receiving little or no treatment.

APPLICABILITY

Filter strips are applicable in most regions, but are restricted in some situations because they consume a large amount of space relative to other practices. Filter strips are best suited to treating runoff from roads and highways, roof downspouts, very small parking lots, and pervious surfaces. They are also ideal components of the "outer zone" of a stream buffer (see Buffer Zones fact sheet), or as pretreatment to a structural practice. This recommendation is consistent with recommendations in the agricultural setting that filter strips are most effective when combined with another practice (Magette et al., 1989). In fact, the most recent storm water manual for Maryland does not consider the filter strip as a treatment practice, but does offer storm water volume reductions in exchange for using filter strips to treat some of a site.

Regional Applicability

Filter strips can be applied in most regions of the country. In arid areas, however, the cost of irrigating the grass on the practice will most likely outweigh its water quality benefits.

AUBURN

SYMBIONT

Ultra-Urban Areas

Ultra-urban areas are densely developed urban areas in which little pervious surface exists. Filter strips are impractical in ultra-urban areas because they consume a large amount of space.

Storm Water Hot Spots

Storm water hot spots are areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in storm water. A typical example is a gas station. Filter strips should not receive hot spot runoff, because the practice encourages infiltration. In addition, it is questionable whether this practice can reliably remove pollutants, so it should definitely not be used as the sole treatment of hot spot runoff.

Storm Water Retrofit

A storm water retrofit is a storm water management practice (usually structural), put into place after development has occurred, to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. Filter strips are generally a poor retrofit option because they consume a relatively large amount of space and cannot treat large drainage areas.

Cold Water (Trout) Streams

Some cold water species, such as trout, are sensitive to changes in temperature. While some treatment practices, such as wet ponds (see Wet Retention Pond fact sheet), can warm storm water substantially, filter strips do not warm pond water on the surface for long periods of time and are not expected to increase storm water temperatures. Thus, these practices are good for protection of cold-water streams.

ADVANTAGES/LIMITATIONS

Filter strips have several limitations related to their performance and space consumption:

- The practice has not been shown to achieve high pollutant removal.
- Filter strips require a large amount of space, typically equal to the impervious area they treat, making them often infeasible in urban environments where land prices are high.
- If improperly designed, filter strips can become a mosquito breeding ground.
- Proper design requires a great deal of finesse, and slight problems in the design, such as improper grading, can render the practice ineffective in terms of pollutant removal.

DESIGN AND SITING

Siting Considerations

In addition to the restrictions and modifications to adapting filter strips to different regions and land uses, designers need to ensure that this management practice is feasible at the site in question. The following section provides basic guidelines for siting filter strips.

VEGETATED FILTER STRIPS

Drainage Area

Typically, filter strips are used to treat very small drainage areas. The limiting design factor, however, is not the drainage area the practice treats but the length of flow leading to it. As storm water runoff flows over the ground's surface, it changes from sheet flow to concentrated flow. Rather than moving uniformly over the surface, the concentrated flow forms rivulets which are slightly deeper and cover less area than the sheet flow. When flow concentrates, it moves too rapidly to be effectively treated by a grassed filter strip. As a rule, flow concentrates within a maximum of 75 feet for impervious surfaces, and 150 feet for pervious surfaces (CWP, 1996). Using this rule, a filter strip can treat one acre of impervious surface per 580-foot length.

Slope

Filter strips should be designed on slopes between 2 and 6 percent. Greater slopes than this would encourage the formation of concentrated flow. Except in the case of very sandy or gravelly soil, runoff would pond on the surface on slopes flatter than 2 percent, creating potential mosquito breeding habitat.

Soils /Topography

Filter strips should not be used on soils with a high clay content, because they require some infiltration for proper treatment. Very poor soils that cannot sustain a grass cover crop are also a limiting factor.

Ground Water

Filter strips should be separated from the ground water by between 2 and 4 ft to prevent contamination and to ensure that the filter strip does not remain wet between storms.

Design Considerations

Filter strips appear to be a minimal design practice because they are basically no more than a grassed slope. However, some design features are critical to ensure that the filter strip provides some minimum amount of water quality treatment.

- A pea gravel diaphragm should be used at the top of the slope. The pea gravel diaphragm (a small trench running along the top of the filter strip) serves two purposes. First, it acts as a pretreatment device, settling out sediment particles before they reach the practice. Second, it acts as a level spreader, maintaining sheet flow as runoff flows over the filter strip.
- The filter strip should be designed with a pervious berm of sand and gravel at the toe of the slope. This feature provides an area for shallow ponding at the bottom of the filter strip. Runoff ponds behind the berm and gradually flows through outlet pipes in the berm. The volume ponded behind the berm should be equal to the water quality volume. The water quality volume is the amount of runoff that will be treated for pollutant removal in the practice. Typical water quality volumes are the runoff from a 1-inch storm or ½-inch of runoff over the entire drainage area to the practice.
- The filter strip should be at least 25 feet long to provide water quality treatment.
- Designers should choose a grass that can withstand relatively high velocity flows and both wet and dry periods.
- Both the top and toe of the slope should be as flat as possible to encourage sheet flow and prevent erosion.

Regional Variations

In cold climates, filter strips provide a convenient area for snow storage and treatment. If used for this purpose, vegetation in the filter strip should be salt-tolerant, (e.g., creeping bentgrass), and a maintenance schedule should include the removal of sand built up at the bottom of the slope. In arid or semi-arid climates, designers should specify drought-tolerant grasses (e.g., buffalo grass) to minimize irrigation requirements.

MAINTENANCE

Filter strips require similar maintenance to other vegetative practices (see Grassed Swales fact sheet). These maintenance needs are outlined below. Maintenance is very important for filter strips, particularly in terms of ensuring that flow does not short circuit the practice.

Table 1. Typical maintenance activities for grassed filter strips (Source: CWP, 1996)

Activity	Schedule
• Inspect pea gravel diaphragm for clogging and remove built-up sediment. • Inspect vegetation for rills and gullies and correct. Seed or sod bare areas. • Inspect to ensure that grass has established. If not, replace with an alternative species.	Annual inspection (semi-annual the first year)
• Mow grass to maintain a 3–4 inch height	Regular (frequent)
• Remove sediment build-up within the bottom when it has accumulated to 25% of the original capacity.	Regular (infrequent)

EFFECTIVENESS

Structural storm water management practices can be used to achieve four broad resource protection goals. These include flood control, channel protection, ground water recharge, and pollutant removal. The first two goals, flood control and channel protection, require that a storm water practice be able to reduce the peak flows of relatively large storm events (at least 1- to 2-year storms for channel protection and at least 10- to 50-year storms for flood control). Filter strips do not have the capacity to detain these events, but can be designed with a bypass system that routes these flows around the practice entirely.

Filter strips can provide a small amount of ground water recharge as runoff flows over the vegetated surface and ponds at the toe of the slope. In addition, it is believed that filter strips can provide modest pollutant removal. Studies from agricultural settings suggest that a 15-foot-wide grass buffer can achieve a 50 percent removal rate of nitrogen, phosphorus, and sediment, and that a 100-foot buffer can reach closer to 70 percent removal of these constituents (Desbonette et al., 1994). It is unclear how these results can be translated to the urban environment, however. The characteristics of the incoming flows are radically different both in terms of pollutant concentration and the peak flows associated with similar storm events. To date, only one study (Yu et al., 1992) has investigated the effectiveness of a grassed filter strip to treat runoff from a large parking lot. The study found that the pollutant removal varied depending on the length of flow in the filter strip. The narrower (75-foot) filter strip had moderate removal for some pollutants and actually appeared to export lead, phosphorus, and nutrients (See Table 2).

Table 2. Pollutant removal of an urban vegetated filter strip (Source: Yu et al., 1993)

	Pollutant Removal (%)	
	75-Ft Filter Strip	150-Ft Filter Strip
Total suspended solids	54	84
Nitrate+nitrite	27	20
Total phosphorus	25	40
Extractable lead	16	50
Extractable zinc	47	55

COST

Little data are available on the actual construction costs of filter strips. One rough estimate can be the cost of seed or sod, which is approximately 30¢ per ft^2 for seed or 70¢ per ft^2 for sod. This amounts to between $13,000 and $30,000 per acre for a filter strip, or the same amount per impervious acre treated. This cost is relatively high compared with other treatment practices. However, the grassed area used as a filter strip may have been seeded or sodded even if it were not used for treatment. In these cases, the only additional costs are the design, which is minimal, and the installation of a berm and gravel diaphragm. Typical maintenance costs are about $350/acre/year (adapted from SWRPC, 1991). This cost is relatively inexpensive and, again, might overlap with regular landscape maintenance costs.

The true cost of filter strips is the land they consume, which is higher than for any other treatment practice. In some situations this land is available as wasted space beyond back yards or adjacent to roadsides, but this practice is cost-prohibitive when land prices are high and land could be used for other purposes.

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The majority of this fact sheet is copied from the United States Environmental Protection Agency Post Construction Stormwater Management in New Development & Redevelopment BMP Fact Sheet for Vegetated Filter Strips (cfpub.epa.gov/npdes/stormwater/menuofbmps/post_11.cfm).

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BMP FACTSHEET
VEGETATED SWALES

VEGETATED SWALES


Source: Puget Sound Online

Water Quantity Benefits (low, medium, high)	
Rate Reduction	**Low**
Volume Reduction	**Low**
Water Quality Benefits (% Reduction)	
Total Suspended Solids (TSS)	**30-90**
Total Phosphorus (P)	**20-85**
Total Nitrogen (N)	**0-50**
Metals	**0-90**
Oil and Grease	**75**
Bacteria	**NA**
Other Considerations (low, medium, high or other)	
Area Typically Served (acres)	**2-4**
% of Area Needed for BMP	**10-20**
Capital Costs	**Low**
O& M Costs	**Low**
Maintenance	**Medium**
Training	**Low**
Effective Life (years)	**5-20**

DESCRIPTION

The term swale (a.k.a. grassed channel, dry swale, wet swale, biofilter) refers to a series of vegetated, open channel management practices designed specifically to treat and attenuate storm water runoff for a specified water quality volume. As storm water runoff flows through these channels, it is treated through filtering by the vegetation in the channel, filtering through a subsoil matrix, and/or infiltration into the underlying soils. Variations of the grassed swale include the grassed channel, dry swale, and wet swale. The specific design features and methods of treatment differ in each of these designs, but all are improvements on the traditional drainage ditch. These designs incorporate modified geometry and other features for use of the swale as a treatment and conveyance practice.

APPLICABILITY

Grassed swales can be applied in most situations with some restrictions. Swales are very well suited for treating highway or residential road runoff because they are linear practices.

Regional Applicability

Grassed swales can be applied in most regions of the country. In arid and semi-arid climates, however, the value of these practices needs to be weighed against the water needed to irrigate them.

Ultra-Urban Areas

Ultra-urban areas are densely developed urban areas in which little pervious surface exists. Grassed swales are generally not well suited to ultra-urban areas because they require a relatively large area of pervious surfaces.

Storm Water Hot Spots

Storm water hot spots are areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in storm water. A typical example is a gas station or convenience store. With the exception of the dry swale design (see Design Variations), hot spot runoff should not be directed toward grassed channels. These practices either infiltrate storm water or intersect the ground water, making use of the practices for hot spot runoff a threat to ground water quality.

Storm Water Retrofit

A storm water retrofit is a storm water management practice (usually structural) put into place after development has occurred, to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. One retrofit opportunity using grassed swales modifies existing drainage ditches. Ditches have traditionally been designed only to convey storm water away from roads. In some cases, it may be possible to incorporate features to enhance pollutant removal or infiltration such as check dams (i.e., small dams along the ditch that trap sediment, slow runoff, and reduce the longitudinal slope). Since grassed swales cannot treat a large area, using this practice to retrofit an entire watershed would be expensive because of the number of practices needed to manage runoff from a significant amount of the watershed's land area.

Cold Water (Trout) Streams

Grassed channels are a good treatment option within watersheds that drain to cold water streams. These practices do not pond water for a long period of time and often induce infiltration. As a result, standing water will not typically be subjected to warming by the sun in these practices.

ADVANTAGES/LIMITATIONS

Grassed swales have some limitations, including the following:

- Grassed swales cannot treat a very large drainage area.
- Wet swales may become a nuisance due to mosquito breeding.
- If designed improperly (e.g., if proper slope is not achieved), grassed channels will have very little pollutant removal.
- A thick vegetative cover is needed for these practices to function properly.

DESIGN AND SITING

In addition to the broad applicability concerns described above, designers need to consider conditions at the site level. In addition, they need to incorporate design features to improve the longevity and performance of the practice, while minimizing the maintenance burden.

Siting Considerations

In addition to considering the restrictions and adaptations of grassed swales to different regions and land uses, designers need to ensure that this management practice is feasible at the site in question because some site conditions (i.e., steep slopes, highly impermeable soils) might restrict the effectiveness of grassed channels.

VEGETATED SWALES

Drainage Area

Grassed swales should generally treat small drainage areas of less than 5 acres. If the practices are used to treat larger areas, the flows and volumes through the swale become too large to design the practice to treat storm water runoff through infiltration and filtering.

Slope

Grassed swales should be used on sites with relatively flat slopes of less than 4 percent slope; 1 to 2 percent slope is recommended. Runoff velocities within the channel become too high on steeper slopes. This can cause erosion and does not allow for infiltration or filtering in the swale.

Soils / Topography

Grassed swales can be used on most soils, with some restrictions on the most impermeable soils. In the dry swale (see Design Variations) a fabricated soil bed replaces on-site soils in order to ensure that runoff is filtered as it travels through the soils of the swale.

Ground Water

The depth to ground water depends on the type of swale used. In the dry swale and grassed channel options, designers should separate the bottom of the swale from the ground water by at least 2 ft to prevent a moist swale bottom, or contamination of the ground water. In the wet swale option, treatment is enhanced by a wet pool in the practice, which is maintained by intersecting the ground water.

Design Considerations

Although there are different design variations of the grassed swale (see Design Variations), there are some design considerations common to all three. One overriding similarity is the cross-sectional geometry of all three options. Swales should generally have a trapezoidal or parabolic cross section with relatively flat side slopes (flatter than 3:1). Designing the channel with flat side slopes maximizes the wetted perimeter. The wetted perimeter is the length along the edge of the swale cross section where runoff flowing through the swale is in contact with the vegetated sides and bottom of the swale. Increasing the wetted perimeter slows runoff velocities and provides more contact with vegetation to encourage filtering and infiltration. Another advantage to flat side slopes is that runoff entering the grassed swale from the side receives some pretreatment along the side slope. The flat bottom of all three should be between 2–8 ft wide. The minimum width ensures a minimum filtering surface for water quality treatment, and the maximum width prevents braiding, the formation of small channels within the swale bottom.

Another similarity among all three designs is the type of pretreatment needed. In all three design options, a small forebay should be used at the front of the swale to trap incoming sediments. A pea gravel diaphragm, a small trench filled with river run gravel, should be used as pretreatment for runoff entering the sides of the swale.

Two other features designed to enhance the treatment ability of grassed swales are a flat longitudinal slope (generally between 1 percent and 2 percent) and a dense vegetative cover in the channel. The flat slope helps to reduce the velocity of flow in the channel. The dense vegetation also helps reduce velocities, protect the channel from erosion, and act as a filter to treat storm water runoff. During construction, it is important to stabilize the channel before the turf has been established, either with a temporary grass cover or with the use of natural or synthetic erosion control products.

In addition to treating runoff for water quality, grassed swales need to convey larger storms safely. Typical designs allow the runoff from the 2-year storm (i.e., the storm that occurs, on average, once every two years) to flow through the swale without causing erosion. Swales should also have the capacity to pass larger storms (typically a 10-year storm) safely.

Design Variations

The following discussion identifies three different variations of open channel practices, including the grassed channel, the dry swale, and the wet swale.

Grassed Channel

Of the three grassed swale designs, grassed channels are the most similar to a conventional drainage ditch, with the major differences being flatter side slopes and longitudinal slopes, and a slower design velocity for water quality treatment of small storm events. Of all of the grassed swale options, grassed channels are the least expensive but also provide the least reliable pollutant removal. The best application of a grassed channel is as pretreatment to other structural storm water practices.

One major difference between the grassed channel and most of the other structural practices is the method used to size the practice. Most storm water management water quality practices are sized by volume. This method sets the volume available in the practice equal to the water quality volume, or the volume of water to be treated in the practice. The grassed channel, on the other hand, is a flow-rate-based design. Based on the peak flow from the water quality storm (this varies from region to region, but a typical value is the 1-inch storm), the channel should be designed so that runoff takes, on average, 10 minutes to flow from the top to the bottom of the channel. A procedure for this design can be found in *Design of Storm Water Filtering Systems* (CWP, 1996).

Dry Swales

Dry swales are similar in design to bioretention areas (see Bioretention fact sheet). These designs incorporate a fabricated soil bed into their design. The existing soil is replaced with a sand/soil mix that meets minimum permeability requirements. An underdrain system is used under the soil bed. This system is a gravel layer that encases a perforated pipe. Storm water treated in the soil bed flows through the bottom into the underdrain, which conveys this treated storm water to the storm drain system. Dry swales are a relatively new design, but studies of swales with a native soil similar to the man-made soil bed of dry swales suggest high pollutant removal.

Wet Swales

Wet swales intersect the ground water and behave almost like a linear wetland cell (see Storm Water Wetland fact sheet). This design variation incorporates a shallow permanent pool and wetland vegetation to provide storm water treatment. This design also has potentially high pollutant removal. One disadvantage to the wet swale is that it cannot be used in residential or commercial settings because the shallow standing water in the swale is often viewed as a potential nuisance by homeowners and also breeds mosquitoes.

Regional Variations

Cold Climates

In cold or snowy climates, swales may serve a dual purpose by acting as both a snow storage/treatment and a storm water management practice. This dual purpose is particularly relevant when swales are used to treat road runoff. If used for this purpose, swales should incorporate salt-tolerant vegetation, such as creeping bentgrass.

Arid Climates

In arid or semi-arid climates, swales should be designed with drought-tolerant vegetation, such as buffalo grass. As pointed out in the Applicability section, the value of vegetated practices for water quality needs to be weighed against the cost of water needed to maintain them in arid and semi-arid regions.

MAINTENANCE

Maintenance of grassed swales mostly involves maintenance of the grass or wetland plant cover. Typical maintenance activities are included in Table 1.

Table 1. Typical maintenance activities for grassed swales (Source: Adapted from CWP, 1996)

Activity	Schedule
• Inspect pea gravel diaphragm for clogging and correct the problem. • Inspect grass along side slopes for erosion and formation of rills or gullies and correct. • Remove trash and debris accumulated in the inflow forebay. • Inspect and correct erosion problems in the sand/soil bed of dry swales. • Based on inspection, plant an alternative grass species if the original grass cover has not been successfully established. • Replant wetland species (for wet swale) if not sufficiently established.	Annual (semi-annual the first year)
• Rototill or cultivate the surface of the sand/soil bed of dry swales if the swale does not draw down within 48 hours. • Remove sediment build-up within the bottom of the swale once it has accumulated to 25 percent of the original design volume.	As needed (infrequent)
• Mow grass to maintain a height of 3–4 inches	As needed (frequent seasonally)

EFFECTIVENESS

VEGETATED SWALES

Structural storm water management practices can be used to achieve four broad resource protection goals. These include flood control, channel protection, ground water recharge, and pollutant removal. Grassed swales can be used to meet ground water recharge and pollutant removal goals.

Ground Water Recharge

Grassed channels and dry swales can provide some ground water recharge as infiltration is achieved within the practice. Wet swales, however, generally do not contribute to ground water recharge. Infiltration is impeded by the accumulation of debris on the bottom of the swale.

Pollutant Removal

Few studies are available regarding the effectiveness of grassed channels. In fact, only 9 studies have been conducted on all grassed channels designed for water quality (Table 2). The data suggest relatively high removal rates for some pollutants, but negative removals for some bacteria, and fair performance for phosphorous.

Table 2. Grassed swale pollutant removal efficiency data

Removal Efficiencies (% Removal)							
Study	**TSS**	**TP**	**TN**	**NO_3**	**Metals**	**Bacteria**	**Type**
Goldberg 1993	67.8	4.5	-	31.4	42–62	-100	grassed channel
Seattle Metro and Washington Department of Ecology 1992	60	45	-	25	2–16	-25	grassed channel
Seattle Metro and Washington Department of Ecology, 1992	83	29	-	25	46–73	-25	grassed channel
Wang et al., 1981	80	-	-	-	70–80	-	dry swale
Dorman et al., 1989	98	18	-	45	37–81	-	dry swale
Harper, 1988	87	83	84	80	88–90	-	dry swale
Kercher et al., 1983	99	99	99	99	99	-	dry swale
Harper, 1988.	81	17	40	52	37–69	-	wet swale
Koon, 1995	67	39	-	9	-35 to 6	-	wet swale
Occoquan Watershed Monitoring Lab, 1983	-100	-100	-100	-	-100	-	drainage channel
Yousef et al., 1985	-	8	13	11	14–29	-	drainage channel
Occoquan Watershed Monitoring Lab, 1983	-50	-9.1	-18.2	-	-100	-	drainage channel
Yousef et al., 1985	-	-19.5	8	2	41–90	-	drainage channel
Occoquan Watershed Monitoring Lab, 1983	31	-23	36.5	-	-100 to 33	-	drainage channel
Welborn and Veenhuis, 1987	0	-25	-25	-25	0	-	drainage channel

Yu et al., 1993	68	60	-	-	74	-	drainage channel
Dorman et al., 1989	65	41	-	11	14-55	-	drainage channel
Pitt and McLean, 1986	0	-	0	-	0	0	drainage channel
Oakland, 1983	33	-25	-	-	20–58	0	drainage channel
Dorman et al., 1989	-85	12	-	-100	14–88	-	drainage channel

While it is difficult to distinguish between different designs based on the small amount of available data, grassed channels generally have poorer removal rates than wet and dry swales, although wet swales appear to export soluble phosphorous (Harper, 1988; Koon, 1995). It is not clear why swales export bacteria. One explanation is that bacteria thrive in the warm swale soils. Another is that studies have not accounted for some sources of bacteria, such as local residents walking dogs within the grassed swale area.

COST

Little data are available to estimate the difference in cost between various swale designs. One study (SWRPC, 1991) estimated the construction cost of grassed channels at approximately \$0.25 per ft^2. This price does not include design costs or contingencies. Brown and Schueler (1997) estimate these costs at approximately 32 percent of construction costs for most storm water management practices. For swales, however, these costs would probably be significantly higher since the construction costs are so low compared with other practices. A more realistic estimate would be a total cost of approximately \$0.50 per ft^2, which compares favorably with other storm water management practices.

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BMP FACTSHEET
LEVEL SPREADER

LEVEL SPREADER

Source: Illinois Urban Manual Practice Standards

Water Quantity Benefits (low, medium, high)	
Rate Reduction	**Low**
Volume Reduction	**Low**
Water Quality Benefits (% Reduction)	
Total Suspended Solids (TSS)	**<25%**
Total Phosphorus (P)	**<25%**
Total Nitrogen (N)	**<25%**
Metals	**<25%**
Oils and Grease	**<25%**
Bacteria	**<25%**
Other Considerations (low, medium, high or other)	
Area Typically Served (acres)	**<2**
% of Area Needed for BMP	**Low**
Capital Costs	**Low**
O& M Costs	**Low**
Maintenance	**Low**
Training	**Low**
Effective Life (years)	**5-20**

DESCRIPTION

Level Spreaders main purpose is to convert concentrated, potentially erosive flow to sheet flow and release it uniformly over a stabilized area or filter strip. The resultant sheet flow enhances pollutant filtering and runoff infiltration and reduces the potential for erosion.

Level spreaders are structures that are designed to uniformly distribute concentrated flow over a large area. Level spreaders come in many forms, depending on the peak rate of inflow, the duration of use, the type of pollutant, and the site conditions. All designs follow the same principle:

1. Concentrated flow enters the spreader through a pipe, ditch, or swale.
2. The flow is retarded and energy is dissipated.
3. The flow is distributed throughout a long linear shallow trench or behind a low berm.
4. Water then flows over the berm/ditch, theoretically, uniformly along the entire length.

APPLICABILITY

The principal application of a level spreader is to convey runoff from impervious surfaces, such as parking lots or roadways, uniformly onto vegetated filter strips. Level spreaders can also be applied as outlets for diversion structures. Level spreaders are appropriate and/or necessary under the following conditions:

1. Where runoff from an impervious surface is uneven and/or runoff is released as concentrated flow, such as through curb cuts or roof downspouts
2. At the ends of diversions
3. Where the runoff water will not reconcentrate after release from the level spreader until it reaches an outlet designed for concentrated flow
4. Where sediment-free storm runoff can be released in sheet flow down a stabilized slope without causing erosion

5. Where the lip of the level spreader can be constructed in undisturbed soil
6. Where there will be no traffic over the spreader.

ADVANTAGES/LIMITATIONS

Level spreaders can enhance the performance of downstream filtering or infiltration BMPs by spreading out the flow.

A level spreader can only handle small flows from ditches or channels. A level spreader with vegetated lip needs to be protected from traffic (even riding mowers) in order to maintain a smooth level surface for the overflow weir.

DESIGN & SIZING

Level spreaders are part of a treatment system. This level spreader system consists of three main parts: 1. Preliminary treatment, 2. Principal treatment, and 3. Emergency treatment. Wet ponds, stormwater wetlands, and sand filters each have the same treatment path as level spreaders.

In determining allowable flows over a level spreader, downstream conditions are considered. In particular, what is the soil covering: grass, mulch, or something else in between such as a thicket. The length of level spreader is determined by what is on the downstream side.

Different ground coverings have different allowable velocities, which is the maximum velocity of water before it causes erosion.

The level spreader length needs to be designed so that velocities are not exceeded. It is important to include in the design the following fact: water will recollect as it flows down slope. Studies have shown that water that has been distributed across the grade may recollect in as little as 10-12 feet. Recollection is inevitable. How much recollection is allowable until flow can no longer be considered sheet flow? It is suggested that once water is using only 33% of available land, sheet flow becomes concentrated flow. The distance down slope of the level spreader where only 33% of available land is used can be described as the level spreader’s Effective Distance, or Ed. Flow beyond the level spreader’s effective distance would be considered to be concentrated, not dispersed.

Level spreaders must be designed, therefore, to ensure non-erosive velocities not only at the time water passes over the level spreader (when flow is theoretically completely dispersed), but at the time water has reached the effective distance. The more limiting parameter is the latter. Level spreaders must be designed so that non-erosive velocities are not exceeded once the flow has traveled the effective distance down slope. Velocities allowed as water flows over the level spreader must be 33% of the erosive velocity experienced at the effective distance down slope. So, if mulch ground covering is able to withstand velocities as high as 2 feet per second (fps) the design velocity over the level spreader needs to be 0.67 fps, or 1/3 of the erosive velocity.

The designer’s main goal with level spreader design is to ensure an appropriate length of a level spreader – a length that does not allow for erosive velocities down slope. Basic sizing guidelines for level spreaders depend on the inflow and the down slope ground cover. For grass, 13’ of level spreader are normally needed for each cfs of flow. For gravel, 9’ of level spreader are normally needed for each cfs of flow. For thicket (shrubs/grasses), 13’ of level spreader are normally needed for each cfs of flow. For mulch (trees/shrubs), 100’ of level spreader are normally needed for each cfs of flow. These guidelines are only applicable up to 10cfs with the exception of the mulch cover in which case 3 cfs is maximum flow.

MAINTENANCE

Inspect level spreaders after every rainfall until vegetation is established, and promptly make needed repairs. After the area has been stabilized, make periodic inspections and maintain vegetation in a healthy, vigorous condition.

Verify that the level spreader is distributing flow evenly. If problems are noted, make appropriate modifications to ensure even flow distribution.

Maintenance concerns include cleaning debris that may accumulate immediately up slope of the level spreader. This prevents long-term clogging. Debris accumulation could be significant if the level spreader is constructed down slope of a construction site. As mentioned in the construction tips section, debris can also gather immediately down slope of the level spreader causing localized damming, forcing the level spreader to have concentrated flow.
With the exception of the concrete construction, level spreaders must be occasionally checked to make sure they are still level. Animals, falling limbs, and differential settling can cause the level spreaders to have low areas on the down slope end, rendering level spreaders no longer level. Livestock should be fenced out. Often simple visual inspection is adequate. The frequency of inspection is dependant upon site conditions, including local traffic (by people and other animals) and weather. Perhaps the best time to inspect is immediately after a large precipitation event.

EFFECTIVENESS

Level Spreaders can provide some sediment removal but they are normally used only to distribute flow upgradient of other BMPs such as vegetative buffer strips. The removal is achieved through the down gradient BMP

COST

Level spreaders are a preferred BMP because they are simple to construct and relatively inexpensive. A two-person crew can construct a 50 feet long wooden or PVC silt fence level spreader in a few hours. Per foot material and equipment cost will range from $3-$10 depending upon the type of level spreader, with the exception of concrete trough level spreaders, which are substantially more expensive.

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BMP FACTSHEET
CATCH BASIN INSERTS

CATCH BASIN INSERTS

Source: Kristar Stormwater Treatment Products Online

Water Quantity Benefits (low, medium, high)	
Rate Reduction	**Low**
Volume Reduction	**Low**

Water Quality Benefits (% Reduction)	
Total Suspended Solids (TSS)	Can vary depending on model chosen.
Total Phosphorus (P)	
Total Nitrogen (N)	
Metals	
Oil and Grease	
Bacteria	

Other Considerations (low, medium, high or other)	
Area Typically Served (acres)	**<1**
% of Area Needed for BMP	**None**
Capital Costs	**Low**
O& M Costs	**Medium -High**
Maintenance	**High**
Training	**Low**
Effective Life (years)	**10-20**

DESCRIPTION

A catch basin (a.k.a. storm drain inlet, curb inlet) is an inlet to the storm drain system that typically includes a grate or curb inlet and a sump to capture sediment, debris, and associated pollutants. They are also used in combined sewer overflow (CSO) watersheds to capture floatables and settle some solids. Catch basins act as pretreatment for other treatment practices by capturing large sediments. The performance of catch basins at removing sediment and other pollutants depends on the design of the catch basin (e.g., the size of the sump) and maintenance procedures to retain the storage available in the sump to capture sediment.

Catch basin efficiency can be improved using inserts, which can be designed to remove oil and grease, trash, debris, and sediment. Some inserts are designed to drop directly into existing catch basins, while others may require extensive retrofit construction.

APPLICABILITY

Catch basins are used in drainage systems throughout the United States. However, many catch basins are not ideally designed for sediment and pollutant capture. Ideal application of catch basins is as pretreatment to another storm water management practice. Retrofitting existing catch basins may help to improve their performance substantially. A simple retrofit option is to ensure that all catch basins have a hooded outlet to prevent floatable materials, such as trash and debris, from entering the storm drain system. Catch basin inserts for both new development and retrofits at existing sites may be preferred when available land is limited, as in urbanized areas.

ADVANTAGES/LIMITATIONS

Catch basins have three major limitations, including:

- Even ideally designed catch basins cannot remove pollutants as well as structural storm water management practices, such as wet ponds, sand filters, and storm water wetlands.
- Unless frequently maintained, catch basins can become a source of pollutants through resuspension.
- Catch basins cannot effectively remove soluble pollutants or fine particles.

DESIGN AND SITING

The performance of catch basins is related to the volume in the sump (i.e., the storage in the catch basin below the outlet). Lager et al. (1997) described an "optimal" catch basin sizing criterion, which relates all catch basin dimensions to the diameter of the outlet pipe (D):

- The diameter of the catch basin should be equal to 4D.
- The sump depth should be at least 4D. This depth should be increased if cleaning is infrequent or if the area draining to the catch basin has high sediment loads.
- The top of the outlet pipe should be 1.5 D from the bottom of the inlet to the catch basin.

Catch basins can also be sized to accommodate the volume of sediment that enters the system. Pitt et al. (1997) propose a sizing criterion based on the concentration of sediment in storm water runoff. The catch basin is sized, with a factor of safety, to accommodate the annual sediment load in the catch basin sump. This method is preferable where high sediment loads are anticipated, and where the optimal design described above is suspected to provide little treatment.

The basic design should also incorporate a hooded outlet to prevent floatable materials and trash from entering the storm drain system. Adding a screen to the top of the catch basin would not likely improve the performance of catch basins for pollutant removal, but would help capture trash entering the catch basin (Pitt et al., 1997).

Several varieties of catch basin inserts exist for filtering runoff. There are two basic catch basin insert varieties. One insert option consists of a series of trays, with the top tray serving as an initial sediment trap, and the underlying trays composed of media filters. Another option uses filter fabric to remove pollutants from storm water runoff. Yet another option is a plastic box that fits directly into the catch basin. The box construction is the filtering medium. Hydrocarbons are removed as the storm water passes through the box while trash, rubbish, and sediment remain in the box itself as storm water exits. These devices have a very small volume, compared to the volume of the catch basin sump, and would typically require very frequent sediment removal. Bench test studies found that a variety of options showed little removal of total suspended solids, partially due to scouring from relatively small (6-month) storm events (ICBIC, 1995).

One design adaptation of the standard catch basin is to incorporate infiltration through the catch basin bottom. Two challenges are associated with this design. The first is potential ground water impacts, and the second is potential clogging, preventing infiltration. Infiltrating catch basins should not be used in commercial or industrial areas, because of possible ground water contamination. While it is difficult to prevent clogging at the bottom of the catch basin, it might be possible to incorporate some pretreatment into the design.

MAINTENANCE

Typical maintenance of catch basins includes trash removal if a screen or other debris capturing device is used, and removal of sediment using a vactor truck. Operators need to be properly trained in catch basin maintenance. Maintenance should include keeping a log of the amount of sediment collected and the date of removal. Some cities have incorporated the use of GIS systems to track sediment collection and to optimize future catch basin cleaning efforts.

One study (Pitt, 1985) concluded that catch basins can capture sediments up to approximately 60 percent of the sump volume. When sediment fills greater than 60 percent of their volume, catch basins reach steady state. Storm flows can then resuspend sediments trapped in the catch basin, and will bypass treatment. Frequent clean-out can retain the volume in the catch basin sump available for treatment of storm water flows.

At a minimum, catch basins should be cleaned once or twice per year (Aronson et al., 1993). Two studies suggest that increasing the frequency of maintenance can improve the performance of catch basins, particularly in industrial or commercial areas. One study of 60 catch basins in Alameda County, California, found that increasing the maintenance frequency from once per year to twice per year could increase the total sediment removed by catch basins on an annual basis (Mineart and Singh, 1994). Annual sediment removed per inlet was 54 pounds for annual cleaning, 70 pounds for semi-annual and quarterly cleaning, and 160 pounds for monthly cleaning. For catch basins draining industrial uses, monthly cleaning increased total annual sediment collected to six times the amount collected by annual cleaning (180 pounds versus 30 pounds). These results suggest that, at least for industrial uses, more frequent cleaning of catch basins may improve efficiency. However, the cost of increased operation and maintenance costs needs to be weighed against the improved pollutant removal.

In some regions, it may be difficult to find environmentally acceptable disposal methods for collected sediments. The sediments may not always be land-filled, land-applied, or introduced into the sanitary sewer system due to hazardous waste, pretreatment, or ground water regulations. This is particularly true when catch basins drain runoff from hot spot areas.

EFFECTIVENESS

What is known about the effectiveness of catch basins is limited to a few studies. Table 1 outlines the results of some of these studies.

Table 1. Pollutant removal of catch basins (percent).

Study	Notes	TSS[a]	COD[a]	BOD[a]	TN[a]	TP[a]	Metals
Pitt et al., 1997	–	32	–		–	–	–
Aronson et al., 1983	Only very small storms were monitored in this study.	60–97	10–56	54–88	–	–	–
Mineart and Singh, 1994	Annual load reduction estimated based on concentrations and mass of catch basin sediment.	–	–	–	–	–	For Copper: 3–4% (Annual cleaning) 15% (Monthly cleaning)

[a] TSS=total suspended solids
COD=chemical oxygen demand
BOD=biological oxygen demand
TN=total nitrogen
TP=total phosphorus

COST

A typical pre-cast catch basin costs between $2,000 and $3,000. The true pollutant removal cost associated with catch basins, however, is the long-term maintenance cost. A vactor truck, the most common method of catch basin cleaning, costs between $125,000 and $150,000. This initial cost may be high for smaller Phase II communities. However, it may be possible to share a vactor truck with another community. Typical vactor trucks can store between 10 and 15 cubic yards of material, which is enough storage for three to five catch basins with the "optimal" design and an 18-inch inflow pipe. Assuming semi-annual cleaning, and that the vactor truck could be filled and material disposed of twice in one day, one truck would be sufficient to clean between 750 and 1,000 catch basins. Another maintenance cost is the staff time needed to operate the truck. Depending on the regulations within a community, disposal costs of the sediment captured in catch basins may be significant.

Retrofit catch basin inserts range from as little as $400 for a "drop-in" type to as much as $10,000 or more for more elaborate designs.

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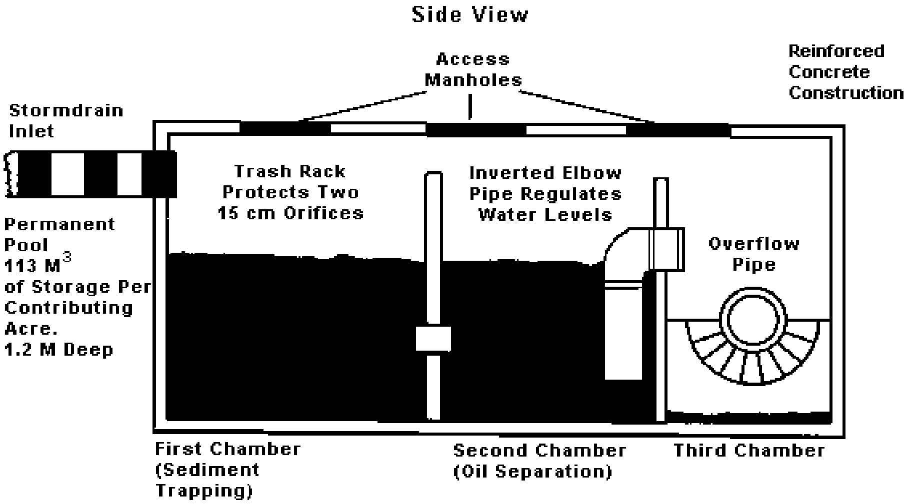
BMP FACTSHEET
OIL-GRIT SEPARATORS

OIL-GRIT SEPARATORS



Source: FHWA

Water Quantity Benefits (low, medium, high)	
Rate Reduction	**Low**
Volume Reduction	**Low**

Water Quality Benefits (% Reduction)	
Total Suspended Solids (TSS)	**20-40**
Total Phosphorus (P)	**<10**
Total Nitrogen (N)	**<10**
Metals	**<10**
Oil and Grease	**50-80**
Bacteria	**NA**

Other Considerations (low, medium, high or other)	
Area Typically Served (acres)	**1-2**
% of Area Needed for BMP	**<1**
Capital Costs	**Low**
O& M Costs	**High**
Maintenance	**High**
Training	**Medium**
Effective Life (years)	**50-100**

DESCRIPTION

The typical oil/grit separator (OGS) unit operates by settling sediment and particulate matter, screening debris, and separating free surface oils from stormwater runoff. The unit typically consists of three or four chambers. The figure above is a schematic of a typical water quality oil/grit separator unit. In the case of a conventional OGS unit, the first chamber, termed the grit chamber, is designed to settle sediment and large particulate matter; the access from the first chamber to the second chamber is covered with a trash rack, which operates as a screen to prevent debris from passing through to the second chamber. The second chamber, termed the oil chamber, is designed to trap and separate free surface oils and grease from the stormwater runoff. The third chamber houses the stormwater outlet pipe that discharges the overflow to the storm drain system.

Most OGS units are designed to be placed in highly impervious parking areas that drain about 0.4 ha (1 ac). Results from one OGS study conducted in the State of Maryland showed that the treatment capacity of most conventional OGS units inventoried was less than 5.1 mm (0.2 in) of runoff for the service area (Schueler and Shepp, 1993). Because of the limited retention capacity, conventional OGSs are not capable of removing large quantities of stormwater constituents. Instead, they are designed and implemented to control hydrocarbons, debris, large organic matter, and coarse sediments that are commonly associated with heavily traveled parking areas.

APPLICABILITY

The OGS unit is designed to trap and settle large sediments and particulate matter, debris, and hydrocarbons from highly impervious areas such as parking lots, gas stations, loading docks, and roadside rest areas. The OGS unit is constructed beneath the surface of the impervious area, and as such does not require additional space. Because of this, it can be easily retrofitted into existing impervious land use conditions, which makes it suitable for ultra-urban environments. Results from an OGS study in the State of Maryland have shown that detention times for conventional OGS units are generally less than 30 minutes during storm events (Schueler and Shepp, 1993). Trapped sediments and particles tend to resuspend during subsequent storms and exit the chambers. Because settling and trapping are temporary, actual pollutant removal occurs only when the units are cleaned out. Therefore, these devices are best suited for an off-line configuration where only a portion of the first flush is treated by the unit and clean out occurs after every major storm event. A study produced by the Metropolitan Washington Council of Governments showed that particulate matter within conventional OGS units remained the same or decreased over a 20-month period (Shepp et al., 1992).

ADVANTAGES/LIMITATIONS

Advantages of oil/grit separators include:

- They are usually located underground so that they minimize use of valuable space.
- They are compatible with storm sewer systems.
- They can pretreat runoff before it is delivered to other BMPs.
- They are easily accessed for maintenance.
- Good longevity with proper maintenance.

Disadvantages of the structures are:

- They have limited pollutant removal capability.
- They require frequent maintenance (i.e. cleanings).
- They have high initial installation costs.
- Cannot be used for removal of dissolved oils
- Does not offer any control over water quantity

DESIGN & SIZING

The OGS unit is a structural BMP that is easily installed in areas of high imperviousness such as parking lots, gas stations, commercial and industrial sites, and shopping centers, and even along roadways. The OGS unit would be well suited for ultra-urban environments where available land area is a major constraint. OGS units typically are sized for highly impervious drainage areas of less than 0.4 ha (1 ac), though up to 0.61 ha (1.5 ac) is feasible. Locating the units off-line would alleviate some of the problems associated with the retention and resuspension of pollutants.

The OGS units are designed using a three- or four-chamber configuration. Settling of larger sediments, trash, and debris takes place in the first chamber. The primary function of the second chamber is to separate oils and grease from the stormwater runoff; some absorption of oils and grease to smaller sediments, and settling will also occur in the first chamber. The third chamber houses the overflow pipe. The OGS unit typically is sized based on the drainage area, which often includes rooftops, and the percent imperviousness of the basin. One common practice is to size the unit based on a design storm to provide some amount of storage. In general, OGS units are rectangular in shape, with the largest chamber being the initial settling chamber. Approximate dimensions for an OGS unit located in a parking area that drains 0.4 ha (1 ac) would be 1.82 m deep by 1.22 m wide by 4.23 long (6 ft deep by 4 ft wide by 14 ft long) (inside dimensions). The length of the first chamber would be 1.82 m (6 ft) with 1.22 m (4 ft) for each of the other two chambers.

Specific dimensions for each OGS design are dependent on site characteristics and local design storm requirements. Improvement in OGS performance can be achieved by extending the interior chamber walls to the top of the chamber, thereby eliminating recirculation and overflow from one chamber to another. In addition, placing the OGS off-line from the main stormwater system helps to reduce resuspension of oil and grit.

Additional design examples and information can be found in Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs (Schueler, 1987), and Northern Virginia BMP Handbook: A Guide to Planning and Designing Best Management Practices in Northern Virginia (NVPDC, 1992). Because studies have shown that water quality inlets are a marginal method for removing particulate matter (Schueler and Shepp, 1993), other design references (Claytor and Schueler, 1996) do not recommend them for sand filter pretreatment.

MAINTENANCE

Very few structural or clogging problems have been reported during the first five years of OGS operation (Schueler and Shepp, 1993). The OGS unit should be inspected after each major storm event. Clean-out would require the removal of sediments, trash, and debris. In reality, OGSs are rarely cleaned out after every storm because such intensive maintenance is beyond most budgets.

The removal of oily debris, sediments, and trash might require disposal as a hazardous waste. However, some local landfills may accept the sediment and trash if it is properly dewatered.

EFFECTIVENESS

Conventional OGS units have demonstrated poor pollutant removal capabilities. The primary removal mechanism of the OGS is settling; with short detention times, and resuspension occurring after every storm event, removal effectiveness is limited to what is physically cleaned out after every storm. If the unit is not cleaned after each storm, resuspended trace metals, nutrients, organic matter, and sediments will eventually pass through each chamber and into the storm drain system.

A study performed on OGS units in the State of Maryland showed that negative sediment deposition from storm to storm indicated that re-suspension and washout were a common problem (Schueler and Shepp, 1993). The only constituent that was trapped with some efficiency in the second chamber was total hydrocarbons. This was probably due to the inverted siphon, which is designed to retain free surface oils and grease (Schueler et al., 1992; Schueler and Shepp, 1993).

COST

OIL-GRIT SEPARATORS

OGS units can be either cast-in-place or precast. Precast concrete chambers are usually delivered to the site partially assembled and tend to cost slightly less than the cast-in-place option. The cost associated with a cast-in-place concrete OGS unit is a function of several parameters. Excavation, gravel bedding, amount and size of rebar, amount of concrete and form work, and grate and clean-out access holes all contribute to the total cost of the OGS unit. In 1992, OGS units were reported to cost between $5,000 and $15,000 fully installed. On average, costs per inlet ranged from $7,000 to $8,000 (Schueler et al., 1992).

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BMP FACTSHEET
POROUS PAVEMENT

POROUS PAVEMENT

Source: Symbiont

Water Quantity Benefits (low, medium, high)	
Rate Reduction	**High**
Volume Reduction	**High**
Water Quality Benefits (% Reduction)	
Total Suspended Solids (TSS)	**82-95**
Total Phosphorus (P)	**60-71**
Total Nitrogen (N)	**80-85**
Metals	**33-99**
Oil and Grease	**0**
Bacteria	**0**
Other Considerations (low, medium, high or other)	
Area Typically Served (acres)	**2-4**
% of Area Needed for BMP	**NA**
Capital Costs	**150% normal pavem.**
O& M Costs	**Medium**
Maintenance	**Medium**
Training	**Low**
Effective Life (years)	**15-20**

DESCRIPTION

Porous pavement is a permeable pavement surface with an underlying stone reservoir to temporarily store surface runoff before it infiltrates into the subsoil. This porous surface replaces traditional pavement, allowing parking lot storm water to infiltrate directly and receive water quality treatment. There are a few porous pavement options, including porous asphalt, pervious concrete, and grass pavers. Porous asphalt and pervious concrete appear to be the same as traditional pavement from the surface, but are manufactured without "fine" materials, and incorporate void spaces to allow infiltration. Grass pavers are concrete interlocking blocks or synthetic fibrous gridded systems with open areas designed to allow grass to grow within the void areas. Other alternative paving surfaces can help reduce the runoff from paved areas but do not incorporate the stone trench for temporary storage below the pavement. While porous pavement has the potential to be a highly effective treatment practice, maintenance has been a concern in past applications of the practice.

APPLICABILITY

The ideal application for porous pavement is to treat low-traffic or overflow parking areas. Porous pavement may also have some application on highways, where it is currently used as a surface material to reduce hydroplaning.

Regional Applicability

Porous pavement can be applied in most regions of the country, but the practice has unique challenges in cold climates. Porous pavement cannot be used where sand is applied to the pavement surface because the sand will clog the surface of the material. Care also needs to be taken when applying salt to a porous pavement surface as chlorides from road salt may migrate into the ground water. For block pavers, plowing may be challenging because the edge of the snow plow blade can catch the edge of the blocks, damaging the surface. This difficulty does not imply that it is impossible to use porous pavement in cold climates. Another concern in cold climates is that infiltrating runoff below pavement may cause frost heave, although design modifications can reduce this risk. Porous pavement has been used successfully in Norway (Stenmark, 1995), incorporating design features to reduce frost heave. Furthermore, some experience suggests that snow melts faster on a porous surface because of rapid drainage below the snow surface (Cahill Associates, 1993).

Ultra-Urban Areas

Ultra-urban areas are densely developed urban areas in which little pervious surface exists. Porous pavements are a good option in these areas because they consume no space. They are not ideal for high-traffic areas, however, because of the potential for failure due to clogging (Galli, 1992).

Storm Water Hot Spots

Storm water hot spots are areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in storm water. These areas include commercial nurseries, auto recycle facilities, commercial parking lots, fueling stations, storage areas, industrial rooftops, marinas, outdoor container storage of liquids, outdoor loading/unloading facilities, public works storage areas, hazardous materials generators (if containers are exposed to rainfall), vehicle service and maintenance areas, and vehicle and equipment washing/steam cleaning facilities. Since porous pavement is an infiltration practice, it should not be applied on storm water hot spots due to the potential for ground water contamination.

Storm Water Retrofit

A storm water retrofit is a storm water management practice (usually structural) put into place after development has occurred, to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. Since porous pavement can only be applied to relatively small sites, using porous pavement as a primary tool for watershed retrofitting would be expensive. The best application of porous pavement for retrofits is on individual sites where a parking lot is being resurfaced.

Cold Water (Trout) Streams

Porous pavement can help to reduce the increased temperature commonly associated with increased impervious cover. Storm water ponds on the surface of conventional pavement, and is subsequently heated by the sun and hot pavement surface. By rapidly infiltrating rainfall, porous pavement reduces the time that storm water is exposed to the sun and heat.

ADVANTAGES/LIMITATIONS

In addition to the relatively strict siting requirements of porous pavement, a major limitation to the practice is the poor success rate it has experienced in the field. Several studies indicate that, with proper maintenance, porous pavement can retain its permeability (e.g., Goforth et al., 1983; Gburek and Urban, 1980; Hossain and Scofield, 1991). When porous pavement has been implemented in communities, however, the failure rate has been as high as 75 percent over 2 years (Galli, 1992).

DESIGN AND SITING

Siting Considerations

POROUS PAVEMENT

Porous pavement has the same siting considerations as other infiltration practices (see Infiltration Trench fact sheet). The site needs to meet the following criteria:

- Soils need to have a permeability between 0.5 and 3.0 inches per hour.
- The bottom of the stone reservoir should be completely flat so that infiltrated runoff will be able to infiltrate through the entire surface.
- Porous pavement should be sited at least 2 to 5 feet above the seasonally high ground water table, and at least 100 feet away from drinking water wells.
- Porous pavement should be sited on low-traffic or overflow parking areas, which are not sanded for snow removal.

Design Considerations

Some basic features should be incorporated into all porous pavement practices. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

1. *Pretreatment*. In porous pavement designs, the pavement itself acts as pretreatment to the stone reservoir below. Because the surface serves this purpose, frequent maintenance of the surface is critical to prevent clogging. Another pretreatment item can be the incorporation of a fine gravel layer above the coarse gravel treatment reservoir. Both of these pretreatment measures are marginal, which is one reason that these systems have a high failure rate.

2. *Treatment*. The stone reservoir below the pavement surface should be composed of layers of small stone directly below the pavement surface, and the stone bed below the permeable surface should be sized to attenuate storm flows for the storm event to be treated. Typically, porous pavement is sized to treat a small event, such as a water quality storm (i.e., the storm that will be treated for pollutant removal), which can range from 0.5 to 1.5 inches. As in infiltration trenches, water can be stored only in the void spaces of the stone reservoir.

3. *Conveyance*. Water is conveyed to the stone reservoir through the surface of the pavement and infiltrates into the ground through the bottom of this stone reservoir. A geosynthetic liner and sand layer should be placed below the stone reservoir to prevent preferential flow paths and to maintain a flat bottom. Designs also need some method to convey larger storms to the storm drain system. One option is to use storm drain inlets set slightly above the elevation of the pavement. This would allow for some ponding above the surface, but would bypass flows that are too large to be treated by the system or when the surface clogs.

4. *Maintenance Reduction*. One nonstructural component that can help ensure proper maintenance of porous pavement is the use of a carefully worded maintenance agreement that provides specific guidance, including how to conduct routine maintenance and how the surface should be repaved. Ideally, signs should be posted on the site identifying porous pavement areas.

   One design option incorporates an "overflow edge," which is a trench surrounding the edge of the pavement. The trench connects to the stone reservoir below the surface of the pavement. Although this feature does not in itself reduce maintenance requirements, it acts as a backup in case the surface clogs. If the surface clogs, storm water will flow over the surface and into the trench, where some infiltration and treatment will occur.

5. *Landscaping*. For porous pavement, the most important landscaping feature is a fully stabilized upland drainage. Reducing sediment loads entering the pavement can help to prevent clogging.

Design Variations

In one design variation, the stone reservoir below the filter can also treat runoff from other sources such as rooftop runoff. In this design, pipes are connected to the stone reservoir to direct flow throughout the bottom of the storage reservoir (Cahill Associates, 1993; Schueler, 1987). If used to treat off-site runoff, porous pavement should incorporate pretreatment, as with all structural management practices.

Regional Adaptations
In cold climates, the base of the stone reservoir should be below the frost line. This modification will help to reduce the risk of frost heave.

MAINTENANCE

Porous pavement requires extensive maintenance compared with other practices. In addition to owners not being aware of porous pavement on a site, not performing these maintenance activities is the chief reason for failure of this practice. Typical requirements are shown in Table 1.

Table 1: Typical maintenance activities for porous pavement (Source: WMI, 1997)

Activity	Schedule
• Avoid sealing or repaving with non-porous materials.	N/A
• Ensure that paving area is clean of debris. • Ensure that paving dewaters between storms. • Ensure that the area is clean of sediments.	Monthly
• Mow upland and adjacent areas, and seed bare areas. • Vacuum sweep frequently to keep the surface free of sediment.	As needed (typically three to four times per year).
• Inspect the surface for deterioration or spalling.	Annual

EFFECTIVENESS

Porous pavement can be used to provide ground water recharge and to reduce pollutants in storm water runoff. Some data suggest that as much as 70 to 80 percent of annual rainfall will go toward ground water recharge (Gburek and Urban, 1980). These data will vary depending on design characteristics and underlying soils. Two studies have been conducted on the long-term pollutant removal of porous pavement, both in the Washington, DC, area. They suggest high pollutant removal, although it is difficult to extrapolate these results to all applications of the practice. The results of the studies are presented in Table 2.

Table 2: Effectiveness of porous pavement pollutant removal (Schueler, 1987)

	Pollutant Removal (%)				
Study	**TSS**	**TP**	**TN**	**COD**	**Metals**
Prince William, VA	82	65	80	-	-
Rockville, MD	95	65	85	82	98–99

COST

Porous asphalt can be more expensive than traditional asphalt. Traditional asphalt is approximately \$2.00 per ft^2 for 3-inches of asphalt on 6-inches of base course (RS Means, 2005). Changing from traditional asphalt to pervious asphalt may add \$1.00 per ft^2 to construction costs for equal pavement depth depending on design (Symbiont bid tabulations). Additional costs may include demolition, stone course, and excavation, if applicable. In addition, the cost of regular vacuum sweeping must be considered.

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BMP FACTSHEET
GREEN ROOFS

GREEN ROOFS

Source: Milwaukee Metropolitan Sewerage District

Water Quantity Benefits (low, medium, high)	
Rate Reduction	Low
Volume Reduction	Low

Water Quality Benefits (% Reduction)	
Total Suspended Solids (TSS)	90
Total Phosphorus (P)	100
Total Nitrogen (N)	20
Metals	80
Oils and Grease	NA
Bacteria	65

Other Considerations (low, medium, high or other)	
Area Typically Served (acres)	Roof size
% of Area Needed for BMP	varies
Capital Costs	$5-15/SF
O& M Costs	medium
Maintenance	medium
Training	low
Effective Life (years)	>20 years

DESCRIPTION

Green roofs reduce water runoff by covering conventional flat or sloped roofs with a waterproof membrane, soil and vegetation. The types of vegetation used on green roofs include grasses, mosses, and even shrubs and trees. Water that does not evaporate or remain in the soil exits the roof through drains or downspouts.

There are two systems of green roofs, extensive and intensive, composed of the same system of layers. Extensive systems are lighter, typically have 4 inches or less of growing medium, use drought tolerant vegetation, and can structurally support limited uses (such as maintenance personnel). Intensive systems are heavier, have a greater soil depth, can support a wider range of plants, and can support increased pedestrian traffic.

APPLICABILITY

Green roofs may be installed on flat roofs or on roofs with slopes up to 30% provided special strapping and erosion control devices are used (Peck and Kuhn, 2003). A green roof may be installed on a newly constructed building, or an existing building can be retrofit with a green roof. Typically if a green roof is > 17 lbs/ft2 (wet), a structural engineer should be consulted (Barr Engineering Co., 2003). Lightweight extensive green roofs can be used in most retrofit projects without costly structural reinforcement.

ADVANTAGES/LIMITATIONS

Advantages

- Green roofs reduce or delay storm water runoff
- Help improve air quality by reducing CO_2 levels
- Insulate buildings, reducing costs of both heating and cooling
- Runoff volume reduction (50 to 60%, Roofscapes, Inc, 2003; Barr Engineering Co., 2003)
- Provides flow attenuation
- Extends the life of a conventional roof

- Provides increased insulation and energy savings
- Reduces air pollution
- Provides habitat for wildlife
- Increases aesthetic value
- Provides sound insulation
- Provides water quality treatment

Disadvantages

- Cost may be greater than a conventional roof
- Feasibility is limited by load-bearing capacity of roof
- Must obtain necessary permits and comply with local building codes such as wind, moisture and fire resistance
- Requires more maintenance than a conventional roof
- Plant survival and waterproofing are potential issues
- May require irrigation

DESIGN & SIZING

Structural load capacity, how much weight the roof can hold, is a major factor in determining whether the green roof is “extensive” or “intensive”. Vegetation selection is based on numerous factors including, growth medium depth, microclimate, irrigation availability and maintenance. A leak detection system is recommended to quickly detect and locate leaks. Modular products can increase installation and repair efficiency.

MAINTENANCE

Green roof maintenance may include watering, fertilizing, and weeding, and is typically greatest in the first two years when plants are becoming established. Maintenance will largely depend on the type of green roof system installed and the type of vegetation planted.

As needed maintenance can include supplement soil substrate/growth medium and control any existing erosion, remove obstructions from drainage inlet, repair or replace drain inlet pipe, remove all fallen leaves and debris from surrounding roof area remove dead vegetation and weeds, replace plants to maintain 90% plant cover, repair or replace parts of irrigation systems, and test automated systems to ensure proper operation.

EFFECTIVENESS

Green roofs have been shown to be effective at removing some pollutants and reducing peak flows associated with storm events. As a general rule, developers can assume that extensive green roofs will absorb 50 percent of rainfall (Stephen Peck, 9/1/2005, personal communication). In a modeling study, Casey Trees and Limno-Tech (2005) assumed that extensive green roofs absorbed two inches of rainfall and intensive green roofs stored 4 inches of rainfall. Due to evapotranspiration and plant uptake, this storage is assumed to recharge once every 4 days. A study by Moran (2005) found that monthly stormwater retention rates varied between 40 percent and 100 percent on two green roofs in the Neuse River watershed, North Carolina. The study showed a decrease in peak flow runoff and total stormwater runoff, and a gradual and delayed release of the stormwater that was ultimately discharged. The reduction of peak flow discharge potentially mitigates stream channel scouring, resulting in improved aquatic habitat and lessening the risk of downstream property damage and flooding.

GREEN ROOFS

COST

Costs range from $5.60/ft2 for extensive roofs to $15/ft2 for intensive roofs plus cost of any structural reinforcement (Stephens, et al, 2002 and Norman Ammermann, personal communication). Operation and maintenance costs are $0.09 to $0.23/ft2/yr (Stephens, et al, 2002). Liptan and Strecker (2003) estimate a similar cost of $5/ft2 to $12/ft2 for a new green roof and $7/ft2 to $20/ft2 for a retrofit. Peck and Kuhn (2003) estimate that the cost of an extensive green roof ranges from $21.60/ft2 to $42.00/ft2, and the cost of an intensive green roof ranges from $40.30/ft2 to $268.50/ft2. Peck and Kuhn's costs include re-roofing and membrane, green roof curbing, drainage layer, filter cloth, growing medium, plants, labor, two years of maintenance, and irrigation. Additionally, design costs are typically 5 to 10 % of the total project cost and administration and site review costs are 2.5 to 5% of the total project cost (Peck and Kuhn, 2003).

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BMP FACTSHEET
RAIN GARDENS

RAIN GARDENS

Source: Wisconsin Department of Natural Resources

Water Quantity Benefits (low, medium, high)	
Rate Reduction	**High**
Volume Reduction	**Medium**

Water Quality Benefits (% Reduction)	
Total Suspended Solids (TSS)	**75**
Total Phosphorus (P)	**50**
Total Nitrogen (N)	**50**
Metals	**75-80**
Oils and Grease	**NA**
Bacteria	**NA**

Other Considerations (low, medium, high or other)	
Area Typically Served (acres)	**<5**
% of Area Needed for BMP	**25**
Capital Costs	**Medium**
O& M Costs	**Low**
Maintenance	**Medium**
Training	**Low**
Effective Life (years)	**5-20**

DESCRIPTION

Rain gardens help capture and slow runoff from your property, reducing the amount of water that gets into the storm and sanitary sewers. Rain gardens use native landscaping to soak up rainwater coming from your downspout or drainage system. The middle part of the garden holds several inches of water, allowing it to slowly infiltrate into the ground instead of being delivered to the storm drain all at once. Rain gardens work best in areas with well-drained soils or by creating well-drained soils.

APPLICABILITY

Rain gardens can be applied to both new and existing developments. Due to space requirements, they are most applicable for residential and light commercial uses. They work best in areas with well-drained soils. Performance can be enhanced in low permeable soils by providing an underdrain system or soil amendments.

ADVANTAGES/LIMITATIONS

Advantages
- Increased public awareness and involvement in stormwater management
- Rain gardens can reduce runoff volume and peak discharge
- Add aesthetics to neighborhoods

Disadvantages
- Can create flooding and visual nuisance if not properly maintained
- Require strong owner and community buy-in

RAIN GARDENS

DESIGN & SIZING

Items to consider when designing a rain garden include

- The rain garden should be at least 10 feet from the house so infiltrating water doesn't seep into the foundation.
- Do not place the rain garden directly over a septic system.
- It may be tempting to put the rain garden in a part of the yard where water already ponds. Don't! The goal of a rain garden is to encourage infiltration and your yard's wet patches show where infiltration is slow.
- It is better to build the rain garden in full or partial sun, not directly under a big tree.
- Putting the rain garden in a flatter part of the yard will make digging much easier.
- Using the slope of the lawn, select the depth of the rain garden from the following options:
  - If the slope is less than 4%, it is easiest to build a 3 to 5-inch deep rain garden.
  - If the slope is between 5 and 7%, it is easiest to build one 6 to 7 inches deep.
  - If the slope is between 8 and 12%, it is easiest to build one about 8 inches deep.
- The size of the rain garden should equal approximately 25% of the upstream drainage area (can be more of less depending on soil type).

MAINTENANCE

- Must be properly maintained to ensure proper performance and reduce public nuisance.
- Require regular watering. However, this significantly reduced or eliminated if native plants are used.
- Weed management and aesthetic maintenance are critical for public acceptance

EFFECTIVENESS

The effectiveness of rain gardens is similar to that of bioretention areas as a rain garden is basically a small scale bioretention area.

COST

The cost to construct a rain garden includes labor for construction and design, plants, and soil mixture. Design and construction costs can vary widely depending complexity of the project. Cost estimates may range form $5 to $10/square foot (Partnership for Rain Gardens, personal communication).

REFERENCES

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University of Wisconsin Extension office, http://clean-water.uwex.edu/pubs/home.htm#rain

BMP FACTSHEET
RAIN BARRELS AND CISTERNS

RAIN BARRELS - CISTERNS

Source: www.ne-design.net

Source: lid-stormwater.net

Water Quantity Benefits (low, medium, high)	
Rate Reduction (small storms)	**Medium**
Volume Reduction (small storms)	**High**

Water Quality Benefits (% Reduction)	
Total Suspended Solids (TSS)	**Varies based on where stored water is released to**
Total Phosphorus (P)	
Total Nitrogen (N)	
Metals	
Oils and Grease	
Bacteria	

Other Considerations (low, medium, high or other)	
Area Typically Served (acres)	**<0.1**
% of Area Needed for BMP	**Low**
Capital Costs	**Low**
O& M Costs	**Low**
Maintenance	**Low**
Training	**Low**
Effective Life (years)	**25**

DESCRIPTION

A rain barrel/cistern is a rainwater harvesting device that is connected to a down spout tube from a house or building. The device collects and stores storm water for use in irrigation during droughts or other uses. Rain barrels are generally plastic 55-gal drums, while cisterns (as pictured below) are much large, often collecting upwards of 1,500 gallons.

APPLICABILITY

Rain barrels are storage devices that collect rainwater from rooftops and are designed to hold between 50-100 gallons of water. They are typically used in residential applications where the collected rainwater is then used for irrigating landscaped areas. Several factors must be considered before employing this practice, including: climate considerations, algae and mosquito control, physical site suitability, and homeowner ability and willingness to operate effectively (Sands and Chapman, 2003).

Cisterns are roof water collection devices that provide retention storage volume in above-ground or underground storage tanks. The water collected can be used for lawn and garden watering, household gray water needs or drinking water supply. Cisterns are generally larger than rain barrels, with some underground cisterns having capacities of 10,000 gallons. Storing rainwater on-site for later re-use also provides an opportunity for water conservation and the possibility of reducing water utility costs (LID Center, 2003).

RAIN BARRELS - CISTERNS

ADVANTAGES/LIMITATIONS

Advantages

Rain Barrels

- Reduces water utility bills
- The practice may not have an impact on CSO's as a stand alone measure; however, it can reduce volumes and peak discharge for frequent events and could reduce costs at treatment plants (Sands and Chapman, 2003)
- Promotes water conservation and increases public awareness and involvement in CSO problems
- Can be retrofit into existing communities
- Requires little space

Cisterns

- Cisterns can reduce the volume of water entering public systems through rooftop storage of large amounts of rainfall
- Promotes water conservation and increased public awareness and involvement in CSO problems
- Reduces water utility bills
- Can be retrofit into existing communities
- Requires little space

Disadvantages

Rain Barrels

- Requires strong homeowner buy-in
- Must have on-site infiltration capacity for rain barrel overflow for larger storm events
- Has limited effectiveness during winter
- Can create foundation problems if not maintained properly
- Can create mosquito problems if not properly maintained

Cisterns

- Requires strong landowner buy-in
- Can be relatively expensive compared to rain barrels
- If collected water is used for drinking, expensive filtration and treatment systems may be required

DESIGN & SIZING

Homemade rain barrels are relatively easy to construct. Basic components consist of the following:

- One or more 55-gallon barrels
- A child-resistant top that allows easy access for cleaning. Screens may be used at the inflow points to strain coarse sediment and reduce the potential for mosquito breeding.
- Connections to the downspout, runoff pipe, and spigot, and hoses to connect barrels in series

Cisterns may also be constructed from raw materials, but prefabricated systems may offer more reliability and greater ease of integration with the building's plumbing system. If adequate structural capacity exists, cisterns can be placed on rooftops and be drained by gravity. Another common installation location is a basement, in which case pumping is needed. Flow splitters can be used to divert the WQ_V to the cistern. An overflow to the sanitary sewer should also be provided.

If cisterns are used to supplement a building's potable plumbing system, a parallel plumbing system will need to be installed. The installation cost depends on the size and purpose of the system and will need to be considered in any cost-benefit analysis. Safety measures must be taken to ensure that cistern water not be used for potable purposes. Besides a parallel plumbing system, such measures include warning signs and lockable faucets.

MAINTENANCE

To avoid nuisance problems, rain barrels require proper maintenance. Mosquito control, ice formation, and overflow drainage are all critical issues that need to be addressed. Barrels should be emptied in winter to prevent ice formation.

Maintenance requirements for cisterns are relatively low if they are only providing a supplemental supply of irrigation water. Cisterns designed for drinking water supply have much higher maintenance requirements, such as biannual testing for water quality and filtering systems. Cisterns, along with all their components and accessories, should undergo regular inspection at least twice a year. Replacement or repair of the unit as a whole, and any of its constituent parts and accessories should subsequently be undertaken if needed (LID Center, 2003).

EFFECTIVENESS

Cisterns and Rain Barrels only provide storage for storm water runoff but can in effect provide treatment of storm water runoff if the water is prevented from reaching the conveyance system. A rain barrel or cistern can provide 100% removal for pollutants if the water is used on the lot after the rain has stopped. This removal only applies to the volume stored so any volume that bypassed the rain barrel/cistern would have received no treatment.

COST

- Although costs vary across manufacturers, the average cost of a single rain barrel ranges from about $100 to $150, with an average of about $120 (LID Center, 2003).
- The cost of cisterns varies greatly depending on size, materials, and location (above or below ground) (LID Center, 2003). The costs can range from $400 for a 200 gallon above ground cistern to $5,000 for a 6,500-gallon underground cistern.
- The total cost of underground reservoirs is nearly double that of above-ground reservoirs (Stuart, 2001).

REFERENCES

Milwaukee Metropolitan Sewerage District, Memorandum Evaluation Of Storm Water Reduction Practices, March 1, 2003

Fairfax County, VA (http://www.lowimpactdevelopment.org/fairfax.htm), LID BMP Fact Sheet – Cisterns/Rain Barrel, February 28, 2005

BMP FACTSHEET
TREE BOX FILTERS

TREE BOX FILTERS

Source: Wisconsin Department of Natural Resources

Water Quantity Benefits (low, medium, high)	
Rate Reduction	**Low**
Volume Reduction	**Low**
Water Quality Benefits (% Reduction)	
Total Suspended Solids (TSS)	**85**
Total Phosphorus (P)	**74**
Total Nitrogen (N)	**68**
Metals	**82**
Oils and Grease	**NA**
Bacteria	**NA**
Other Considerations (low, medium, high or other)	
Area Typically Served (acres)	**0.5**
% of Area Needed for BMP	**Low**
Capital Costs	**Low**
O& M Costs	**Low**
Maintenance	**Low**
Training	**Low**
Effective Life (years)	**25**

DESCRIPTION

Tree box filters are mini bioretention areas installed beneath trees that can be very effective at controlling runoff, especially when distributed throughout the site. Runoff is directed to the tree box, where it is cleaned by vegetation and soil before entering a catch basin. The runoff collected in the tree-boxes helps irrigate the trees.

APPLICABILITY

Tree box filters can receive runoff from both streets and parking lots, as long as a downstream inlet or outfall is present. All land uses are suitable.

ADVANTAGES/LIMITATIONS

Tree box filters can reduce the runoff volume and peak discharge rate for small, frequently occurring storms by capturing the water quality volume (WQV). They are not intended to capture volumes larger than the WQV, or to detain the WQV for extended periods of time, however. Volumes larger than the WQV can be detained in a subsurface storage system (e.g. gravel bed) downstream.

DESIGN & SIZING

To treat 90% of the annual runoff volume, tree box filter surface area should be approximately 0.33% of the drainage area. Tree boxes must be regularly spaced along the length of a corridor as appropriate to meet the annual treatment target. A standard curb inlet must be located downstream of the tree fox filter to intercept bypass flow. Tree box filters are off-line devices and should never be placed in a sump position (i.e. low point). Instead, runoff should flow across the inlet (e.g. left to right). Also, tree box filters are intended for intermittent flows and must not be used as larger event detention devices.

Tree box filters consist of a precast concrete container, a mulch layer, bioretention media mix, observation and cleanout pipes, underdrain pipes, one street tree or large shrub, and a grate landscape cover. Pretreatment under normal conditions is not necessary.

TREE BOX FILTERS

MAINTENANCE

Maintenance consists of annual routine inspection and the regular removal of trash and debris. The mulch will need to be replenished one (1) to two (2) times per year. The cleanout pipe can be used to flush the system if the underdrain becomes clogged. During extreme droughts, the trees or shrubs may need to be watered in the same manner as any other landscaping. The plants may need to be replaced every few years.

To ensure proper performance, visually inspect that storm water is infiltrating properly into the tree box filter. Excessive volumes of stormwater bypassing the tree box filter to the standard inlet may indicate operational problems. Corrective measures to restore performance include inspection for accumulated sediments and debris and removal, if necessary. In instances where the condition of the soil media has degraded significantly, the media and vegetation should be removed and replaced. Inspection and maintenance should occur on an annual or semi-annual basis. Maintenance activities include:

- Excavate, clean and or replace filter media (sand, gravel, topsoil) to insure adequate infiltration rate.
- Plug holes in planter that are not consistent with the original design.
- Allow water to flow directly through the planter to the ground.
- Remove litter and debris, including fallen leaves from deciduous plants and accumulated sediments from the planter.
- Repair all cracks and structural deficiencies in planter.
- Add mulch to planter soil.
- Replant, and prune or remove plants that interfere with planter operation.

EFFECTIVENESS

Tree box filters remove pollutants through the same physical, chemical, and biological mechanisms as bioretention cells. To achieve expected removal efficiencies, the filter surface area should be at least 0.33% of the drainage area. In other words the drainage area to a 6' x 6' tree box (standard size) must be 0.25 acres or less.

COST

A standard 6' x 6' tree box filter costs approximately $8,000. This estimate includes two years of operating maintenance and filter material and plants. Installation costs are approximately $1500 per unit. Annual maintenance is $500 per unit when performed by the manufacturer and $100 per unit when performed by the owner.

REFERENCES

Fairfax County, VA (http://www.lowimpactdevelopment.org/fairfax.htm), LID BMP Fact Sheet – Tree Box Filters, February 28, 2005

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