Indiana Storm Water Quality Manual

Planning and Specification Guide for Effective Erosion and Sediment Control and Post-Construction Water Quality

IDEM
INDIANA DEPARTMENT
OF ENVIRONMENTAL MANAGEMENT

INDIANA STORM WATER QUALITY MANUAL

Planning and Specification Guide for Effective Erosion and Sediment Control and Post-Construction Water Quality

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Some of the materials presented in this manual have been adapted from similar storm water/erosion and sediment control manuals and documents published by several other states, the United States Environmental Protection Agency, and private consulting firms. A list of these references can be found in the appendices of this manual.

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PREFACE

This manual is a comprehensive resource of planning principles and standards that can be implemented as land is being developed. The manual is a basic reference for the preparation of a storm water pollution prevention plan and for the design, installation, and maintenance of individual storm water quality measures. It is intended to help land users and others comply with state and local storm water quality regulations.

This manual replaces the Indiana Handbook for Erosion Control in Developing Areas. The Indiana Storm Water Quality Manual expands on the basic planning principles and storm water quality measures presented in the original handbook. The manual not only addresses erosion and sediment control, but provides a discussion on environmentally sensitive design and post-construction storm water quality measures.

The manual has been prepared as part of the Indiana Department of Environmental Management's public education and outreach efforts. IDEM's Office of Water Quality will continue its efforts to protect Indiana's natural resources by supporting education and training through the development and distribution of technically accurate reference materials and the promotion and utilization of economically feasible storm water quality principles and procedures.

The Indiana Storm Water Quality Manual is a companion manual to the Indiana Drainage Manual, which is an administrative and technical guide that describes management measures associated with drainage activities. The scope of the Indiana Drainage Manual is limited to agricultural drainage improvement activities that take place within or immediately adjacent to Indiana drainage-ways. Although there are several measures that are duplicated in this manual and the Indiana Drainage Manual, each manual is unique in its application. Depending on the nature of the project and the activities involved, the user may choose to maintain a copy of each document. For more information or to order a copy of the Indiana Drainage Manual, please contact:

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www.IN.gov/dnr/water/surface_water/DrainageHandbook

FORWARD

Each year thousands of acres of Indiana land undergoes disturbance and/or is converted for the construction of subdivisions, commercial and industrial centers, highways, and other land uses. Agriculture and urban development are the two major types of land-disturbing activities in Indiana. Both are very important to the economic well being of the citizens of the state. Without proper planning and the wise selection of storm water management measures, these areas of soil disturbance are very vulnerable to accelerated erosion and sedimentation.

Whenever vegetation is removed from the land's surface, the soil becomes exposed to the erosive effects of wind and water. Although erosion is a natural process, it can be greatly accelerated by human action that disturbs the land's surface. While it is true that the tons of soil eroded on agricultural lands is much greater, it has been proven that the amount of soil eroded on a per-acre basis can be many times greater on active construction sites. The loss of soil through erosion commonly results in the loss of good topsoil and the associated minerals and nutrients required for plant establishment and growth.

Soil erosion not only causes on-site damage problems, but can also negatively impact water quality downstream through sediment pollution. It has been shown that sediment is the number one water quality pollutant by volume in Indiana.

Sediment damage can take many forms. Sediment accumulation in wetlands can reduce their capacity to retain storm water and its value to wildlife. Sediment deposition in storm sewers can reduce their efficiency and capacity. Sediment, and accompanying nutrients, often reaches lakes and leads to algal blooms, a decrease in lake depth, and a decrease in the recreational and aesthetic value of the lake.

In addition to erosion and sediment damage, the building of residential subdivisions, shopping centers, industrial parks, schools, recreational attractions, etc. can have a significant effect on the patterns and amounts of storm water runoff during and after construction takes place. This often leads to water quality degradation and more frequent flooding events. The final land use associated with many projects will also contribute to the discharge of pollutants. These pollutants will typically be generated by the activities that are associated with the final land use.

It is important to practice effective storm water management and treatment of storm water runoff before, during, and after construction. Otherwise, the land-owner and/or public may end up paying more for project reconstruction and replacement/maintenance of existing infrastructure. Furthermore, public environmental awareness demands that land users work with nature, and not against it, to protect Indiana's land and water resources.

There are many ways to minimize the impacts of urbanization and protect the integrity of Indiana's natural resources. One method is through careful planning and inclusion of proven storm water management measures in a project's construction and development plans. Careful planning can prevent or at the very least alleviate much of the damage caused by erosion and sedimentation and the pollutants that will be associated with the final land use. However, careful planning and incorporation of appropriate storm water quality measures into a project's construction plans is not enough. These measures must be deployed and maintained on the site throughout all construction phases.

This manual provides engineers, developers, builders, contractors, government officials, and others with guidelines and specific storm water quality measures for controlling soil erosion; controlling and treating the nonpoint source pollution associated with sediment-laden runoff; and the management and treatment of pollutants associated with post-construction land uses. Adhering to these guidelines and properly applying appropriate storm water quality measures will help minimize the adverse impacts that land disturbance, construction activity, and development can have on soil and water resources, and ultimately, the cost of those impacts to society as a whole. In addition to a variety of storm water quality measures, the manual also discusses the philosophy and planning procedures critical to developing an effective storm water pollution prevention plan.

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Chapter 1 discusses storm water runoff, potential pollutants, and the impacts that are associated with land disturbance, construction activity, and final land use.

CHAPTER 2

Construction Site Assessment & Planning

Chapter 2 provides a step-by-step process for site assessment and planning. Information includes site assessment, inventory, data collection, availability of resource information, and final analysis of data. Site assessment and planning are critical to all projects to ensure that all resource issues are adequately addressed and planning of the project will best match the resource issues associated with the site.

CHAPTER 3

Construction Plans

Chapter 3 provides a brief description of the purpose and content of construction plans and outlines several key elements that should be included in the plans.

CHAPTER 4

Planning Principles & Design Considerations

Chapter 4 discusses site planning principles and design considerations, including preservation of natural site features, land/site utilization, and planning principles. This chapter discusses development of a project layout and design that best utilizes the natural features of the project site and incorporates planning principles that reduce impervious surfaces. Some of the design considerations in this section may require the project designer to work with local plan departments to receive waivers or variances from local subdivision ordinances.

CHAPTER 5

Storm Water Pollution Prevention Plan

Chapter 5 provides:

- A description of how to prepare a storm water pollution prevention plan;
- A step-by-step procedure that walks the plan designer through the process of developing a plan that addresses pollution prevention from preconstruction all the way through the final land use;
- Information on the assessment of pollutants associated with preconstruction, construction, and post-construction activities; and
- Guidance in developing a construction sequence schedule and selecting appropriate storm water quality measures that will minimize the impact of pollutants generated during construction phases as well as those generated from the inherent land use after the final project is completed.

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Chapter 6 targets the implementation of the storm water pollution prevention plan including preconstruction meetings, plan implementation, developing a quality assurance plan, and implementing a maintenance schedule.

CHAPTER 7

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Chapter 7 describes and illustrates various erosion and sediment control measures associated with construction activities. In addition, there are several measures that address site management and techniques specifically targeted to other pollutants that are associated with construction activities. Information provided under each measure typically includes a definition, purpose, design and construction guidelines/specifications, installation/application, and maintenance. These measures should be evaluated for feasibility and designed by a qualified individual. All structural measures should be designed by a professional engineer.

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Chapter 8 describes and illustrates various structural storm water quality measures associated with post-construction reduction of storm water pollutants. Information provided under each measure typically includes a description and the applicability of the measure, design and construction guidelines/specifications, and where to find additional information about the measure. These measures should be evaluated for feasibility and designed by a qualified individual. All structural measures should be designed by a professional engineer.

CHAPTER 9

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Chapter 9 contains information related to program management and maintenance, education and public outreach, and regulatory approaches to storm water quality.

Appendices

The appendices contain a glossary of common terms, a list of exhibits and worksheets for many of the storm water quality measures contained in Chapter 7 of the manual, technical information on various erosion and sediment control measures and materials, and a list of references in the writing of this manual.

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CHAPTER 1

Storm Water Runoff and Its Impact

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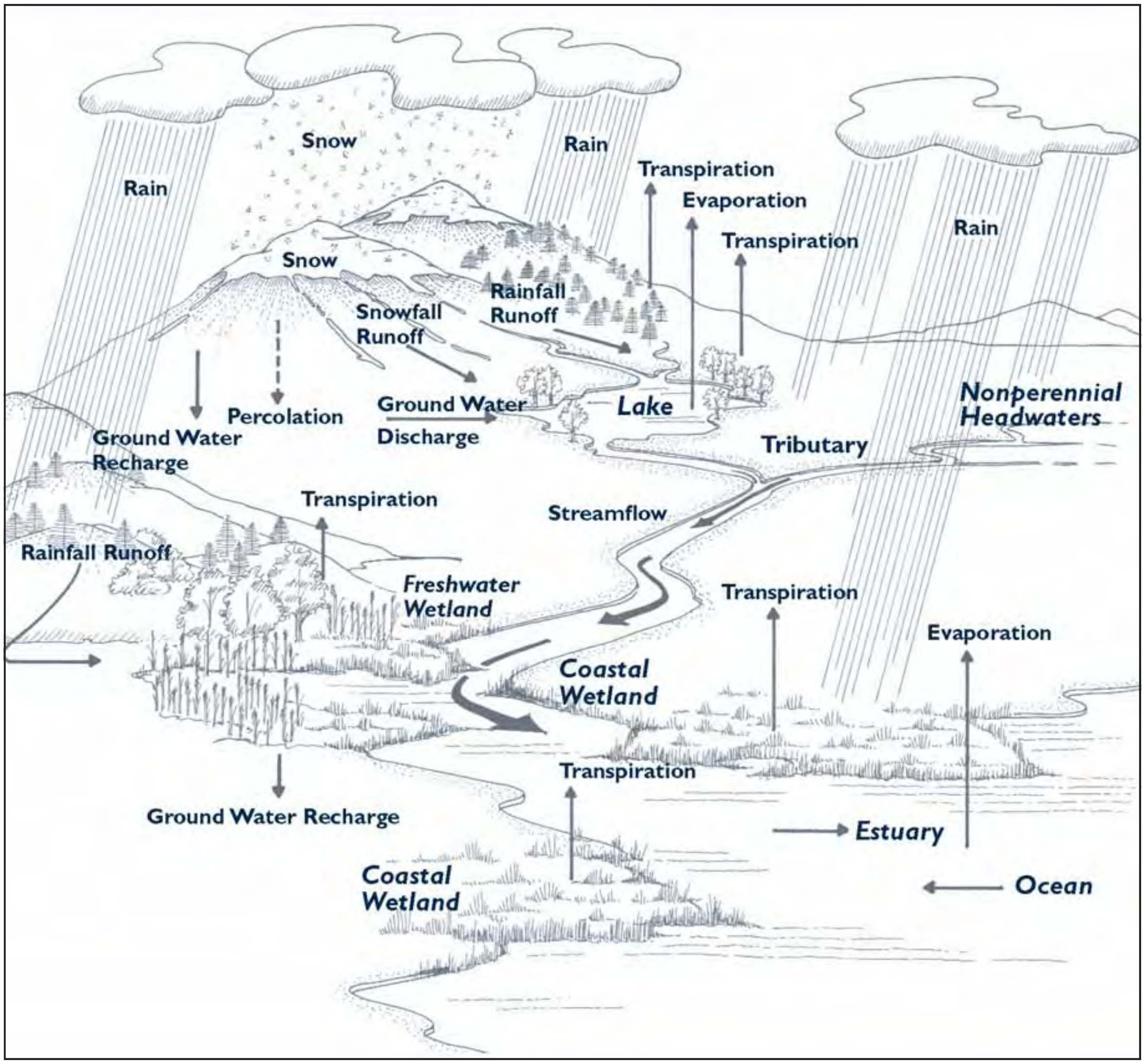
INTRODUCTION TO STORM WATER RUNOFF

Storm water runoff is a part of the earth's hydrological cycle. The hydrological cycle is a conceptual model that describes the distribution and movement of water between the atmosphere, land, and water. The hydrologic cycle can be characterized by the diagram below.



Source: National Water Quality Inventory, U.S. Environmental Protection Agency, 1998

Water that reaches the surface of the earth may:

- Percolate directly into the ground where it can be stored as groundwater or slowly migrate toward a waterbody.
- Flow into a creek, river, wetland, lake, or other natural features.
- Be taken up by roots of trees, grass, and other plants.
- Return to the atmosphere through evaporation, which is the transformation of water from a liquid into a gas.
- Return to the atmosphere through transpiration, which is the process whereby plants release water vapor back into the atmosphere through their leaves.

INTRODUCTION TO STORM WATER RUNOFF

Precipitation that reaches the surface of the earth is either absorbed by the soil through percolation or flows overland as runoff. Vegetative cover enhances absorption by intercepting the rainfall, slowing runoff, and providing root channels that promote infiltration.

Storm water runoff is the volume of water generated by a rainfall event, snowmelt, or other forms of precipitation that falls to the earth's surface and does not infiltrate into the ground. Runoff can be directly correlated with a specific land use. Runoff associated with a forested landscape will typically be less than runoff from an urbanized landscape.

Following rainfall events or snowmelt, runoff flows overland and picks up materials including but not limited to trash, debris, sediments, and pollutants. The runoff can often contain pollutants in quantities that will affect water quality. Runoff can carry a variety of pollutants that are associated with a specific land use. These materials can remain in solution or attach to sediment and will eventually be deposited in the lowest part of the landscape or discharged to creeks, rivers, lakes, and wetlands.

Storm water volume and runoff rates are directly related to the impervious surface area in a watershed. Land development and urbanization typically increase surfaces that are impervious. During construction an increase in runoff can often be attributed to compaction by heavy equipment. Typical urban landscapes have a high percentage of impervious surfaces due to parking lots, rooftops, roads, and highways.

The remainder of this chapter will focus on the pollutants associated with construction and urbanization and their impact to water quality.

A watershed's physical, chemical, and biological characteristics are generally altered when land undergoes some type of development. The watershed's storm water runoff quantity and quality can also be significantly affected. This is particularly true when undeveloped or agricultural land is converted to urban uses. For example, the hydrologic changes in an urban watershed are often magnified due to an increase in impervious surfaces such as rooftops, streets, sidewalks, and parking lots. This increase in impervious surface area usually decreases the amount of time it takes for storm water runoff to move from remote areas of the watershed to the receiving stream or waterbody. In addition, urban development usually requires the construction of storm water conveyance systems which are typically designed to convey storm water runoff in an efficient manner without regard for its impact. Therefore, not only is it quicker for storm water runoff to flow over paved surfaces versus a natural landscape, but these conveyance systems can expedite drainage into the nearest receiving waterbody. The overall result is a significant change to the predevelopment hydrologic conditions of the watershed. A drop of water that used to take hours or days to make its way through the watershed to a receiving waterbody now takes a matter of minutes or hours.

Another impact from altering a watershed's hydrology is an increase in peak runoff volumes. Increased peak runoff volumes can increase the frequency and severity of stream flooding during storm events. Conversely, during non-storm periods the flow in the channel or stream can be diminished greatly or in some instances there may be no flow in the channel or stream.

Peak runoff volumes are typically the result of an increase in impervious surface areas. An increase in peak runoff volumes generally results in the alteration of stream channels, natural drainageways, and riparian habitats. These alterations can have a significant impact on the reduction, and in some instances the elimination, of aquatic vegetation and organisms and can degrade water quality. Other potential effects include increased streambank erosion and streambed scouring, channel siltation, increased water temperatures, decreased dissolved oxygen levels, and changes to the morphology of the watercourse.

Increased pollutant loadings and discharges are still another impact of urban storm water runoff from impervious surface areas. Pollutants associated with urban areas are specific to the type and intensity of the land use. Some examples of pollutants associated with urban land uses include sediments, nutrients, oxygen demanding substances, road deicing agents, heavy metals, oils and grease, hydrocarbons, and bacteria. Runoff from commercial land uses such as shopping centers, business districts, office parks, and parking lots or garages may contain high hydrocarbon loadings and metal concentrations. Pollutant loadings from these types of land uses can be a significant pollutant source in storm water runoff and can be attributed to heavy traffic volumes and large impervious surface areas.

Gas stations are one type of land use that is often designated as a commercial land use and are subject to the same controls as shopping centers and office parks. However, gas stations may generate higher concentrations of heavy metals, hydrocarbons, and other automobile-related pollutants. This is because of the type of day-to-day activities associated with the industry and the volume of clientele that use the facilities. There is also a higher probability for spills to occur at these facilities because of human error.

Protecting or improving water quality in existing urban areas is often difficult because of diverse pollutant loadings, large storm water runoff volumes, limited areas suitable for surface water runoff treatment systems, high costs associated with structural implementation of storm water measures, and the nonexistence of natural or manmade buffer zones. Most existing urban developments have typically been built without consideration for water quality protection. The objective during construction was more likely focused on using the land to its greatest potential for the planned land use. With this approach it is often difficult to address the reduction of pollutants after the fact due to space limitations and the inability to choose the most cost-effective and efficient measure to achieve pollutant removal. However, numerous opportunities exist to address storm water quality impacts and build storm water quality control and treatment measures into projects which propose to convert areas into urban landscapes.

The alteration of the soil probably has the greatest impact on water quality. Therefore, soil should be the first consideration for any proposed land use change. Soil is a subsystem, with a unique set of characteristics such as soil structure and permeability, within the earth's ecosystem. The primary function of soil is to support life. Therefore, there is a natural balance and interrelationship between soil, microorganisms, plants, and animals. This delicate balance can be significantly altered as a result of land use changes and construction activities. These human activities can affect the natural soil characteristics and health of the ecosystem in varying degrees. Changes to the soil ecosystem can be physical such as alteration or destruction of the soil structure while others may be biological or chemical. For example, construction and land disturbance can cause changes in the number and type of organisms that live in the soil. Loss of this soil biota leads to erosion, loss of humus (organic matter), loss of soil structure, and increased potential for soil compaction.

Soil erosion on construction sites has been said to have impacts that are more costly and severe than those of non-construction site impacts. More specifically, erosion causes the depletion of an important resource, nutrient rich topsoil, and often results in degradation of water quality. This is typically due to increased sediment loads and pollutants attached to the soil particles. Excessive sediment deposited on productive agricultural lands or forestlands can also make them sterile and unproductive.

Sediment is the most common pollutant associated with storm water runoff from construction sites. In fact, it has been shown that sediment is the number one pollutant, by volume, of surface waters of the United States. Sediment is also the primary pollutant that is addressed by state and local officials when they regulate construction projects. However, there are several other pollutants associated with construction activities. Some of these pollutants include, but are not limited to, solid wastes, nutrients, pesticides, petroleum products, and chemicals associated with construction activities.

The nature of the construction activity plays an important role in the types of pollutants that may be released from a construction site. For example, construction activities that result in massive earthmoving are likely to have a higher potential for off-site pollutant discharge. An alternative is to develop a project in phases and work with the natural landscape of the site which will result in minimal land disturbance and a reduction in the generation of pollutants. On projects where heavy equipment is utilized there is potential for the release of pollutants from vehicle refueling, fuel storage facilities, and equipment and maintenance areas.

The amount, intensity, and frequency of rainfall; soil type (infiltration rate, organic matter content, etc.); soil surface roughness; slope length and steepness; and ground cover (vegetated or unvegetated) are other factors that can have a significant impact on the amount of pollutants discharged to surface waters and ground water. In addition, the location of the construction site in relation to the receiving waters can have an overall impact on water quality.

The consequences of erosion and subsequent sedimentation can be far-reaching. It has been estimated that on average, one acre of land under construction contributes almost 30 tons of sediment to nearby lakes, rivers, and streams (Source: Wisconsin Department of Natural Resources). In fact, small streams show the most pronounced effects of sediment pollution because they are more easily clogged with sediment. This is primarily due to the stream's size. These small streams account for 86 percent of all stream and river miles in the continental United States (Source: "Protecting our Water," Delaware Nature Society). Therefore, sediment pollution is a major concern across the United States because of the high percentage of small streams and their susceptibility to clog with sediment.

In addition to clogging small stream channels, sediment accumulation is a concern because it decreases the channel's capacity to carry water. This increases the frequency of flooding and can lead to streambank erosion or scour. In fact, urbanization and associated construction activities can increase the occurrence of small floods by a factor of ten or more. High sediment loads and increased frequency of flooding also expedites the shifting or movement of a stream channel as the channel tries to compensate for its reduced capacity.

Another consequence of construction site erosion is that the resulting sediment is often deposited in low, depressional areas such as lakes, ponds, and wetlands that collect and retain surface water runoff. As sediment accumulates in the bottom of these areas, it slowly decreases the depth in which water can stand. As the water depth decreases in these enclosed ecosystems, the system loses its ability to support the plant, animal, and microorganism system it supported with the greater water depths. This issue is becoming a widely recognized problem, especially in natural wetland areas.

Wetland plants and microorganisms are very efficient at removing pollutants from surface water runoff, but as an ecosystem's capacity is diminished its filtration ability decreases. The end result is infilling of the wetland area and loss of habitat for the plants and microorganisms.

It is important to recognize that many depressional areas often serve as ground water recharge areas. As sediment accumulates in the bottom of these depressions it reduces the amount of water the depression can hold. In addition, the sediment seals over the bottom of the depression which then restricts or prevents ground water recharge.

Perhaps the most evident change to any landscape undergoing land-disturbing activities is removal or alteration of the vegetative cover. Vegetative cover plays a very important role in protecting soil resources and improving or maintaining water quality. Many plants have an inherent ability to cleanse water. They take up chemicals and heavy metals from the soil and/or water as they take up the nutrients they need to grow. Some plants are even able to alter the chemistry of the pollutants so that they can not be readily absorbed by animals and humans. The plants can then release the altered, benign pollutant(s) into the soil, water or air. Removal of vegetation can have a profound effect on soil and water quality because the ability to filter or cleanse runoff is lost with the loss of the vegetation.

Removal of vegetation from the soil surface has an immediate impact on the ecosystem. Almost immediately after vegetation is removed, the exposed soil begins to undergo erosion because plant roots are no longer available to grip the soil particles for plant stabilization and provide channels for air and water to circulate through the soil. The removal of plants also reduces the humus content, which binds the soil together in aggregates and gives the soil structure. Without plants, the structure of the soil begins to break down and the soil dries out. The soil then becomes susceptible to the erosive forces of wind and water and the negative impacts that construction equipment and machinery have on soil stability. Thus, the erosion process has begun.

Nutrients, pesticides, and heavy metals are easily absorbed onto exposed surfaces of the loosened soil particles once they have become detached and eroded. The eroded soil particles and attached contaminants are free to move throughout the environment. As these soil particles move, they can accumulate as polluted or contaminated sediments in the landscape or in waterbodies such as lakes or streams.

Vegetation has the ability to reduce storm water runoff because it slows storm water runoff velocities which in turn allows the runoff to infiltrate into the underlying soil. Grasses and larger plants such as trees often create an extensive, fibrous root system that helps bind the soil together and provides channels for the infiltration of water and air. In addition, leaf and needle

litter frequently acts as a sponge, reducing the flow of storm water runoff and increasing infiltration into the underlying soil. As these materials decay, they add humus to the soil. This helps loosen the soil and promotes the formation of soil structure which in turn promotes the infiltration of surface water.

In regard to erosion, vegetative canopies act like an umbrella to protect the soil from raindrop impact. Decaying plant stems and leaves and leaf and needle droppings provide a mulch cover over the soil surface which again protects the soil from raindrop impact.

Urban forestry management is another vegetative measure that can have an impact on soil and water quality. Trees can buffer the effects of climate extremes. For example, during summer months, they provide shade and can reduce home cooling costs. During winter months, they provide protection from the wind, reducing home heating costs and trapping snow which helps recharge soil moisture in the spring.

Source: Natural Resources Conservation Service, Iowa

A forest's age is important in protecting soil and water quality and providing food and habitat for wildlife. Leaf litter and woody debris are important food and habitat sources for animals and organisms that live in and around the ecosystem, particularly in headwater reaches of a stream. Small aquatic organisms ingest and break down the decaying plant materials. Higher-order organisms feed on the smaller organisms and may transform some of the leaf litter and debris. Areas of newly planted trees usually lack this accumulation of leaf and needle litter and vegetative understory. Areas of newly planted trees are also less effective at preventing erosion verses a well-established forest that has a dense canopy and well-established root system. Therefore, protecting and preserving established forests should be a very important component of any land use change when forests are present. It is important to note that forest succession is a lengthy process. It typically requires several years to establish a diverse, complex mix of mature trees and saplings with well-developed root systems, a well-developed understory, and an adequate cover of downed trees, leaves, and leaf and needle litter.

Another impact of urbanization is the effect it can have on food and habitat for aquatic organisms, aquatic insects, fish, amphibians, freshwater mussels, wildlife, and so on. Water quality can affect the diversity and abundance of plant and animal species living in the ecosystem, feeding and mating habits, and nesting and resting areas. Numerous studies have examined the link between watershed urbanization and its impact on stream and wetland biodiversity. These studies reveal that a relatively small amount of urbanization (as little as 10 percent impervious cover) has a negative effect on aquatic diversity. The hydrologic, physical, and water quality changes caused by watershed urbanization all stress the aquatic community and collectively diminish the quality and quantity of available habitat. As a result, these stressors generally cause a decline in biological diversity, a change in trophic structure, and a shift towards more pollution-tolerant organisms.

Urban conditions that negatively affect biodiversity include deposition of sediment in streambed substrate, large woody debris removal, stream crossings, increased water temperatures, increased pollutant loads, decreased base flows, loss of pools and riffles, channel straightening or hardening, increase in turbidity, and algae blooms.

Unfortunately, when land undergoes development much of the existing vegetation is unintentionally damaged or it is removed to provide for the construction of roads, parking areas and buildings. As vegetation is removed animals become displaced and they are required to seek other food sources and habitat. Often, these displaced animals struggle to adapt to their new environment. Aquatic organisms, aquatic insects, fish, amphibians, freshwater mussels, wildlife, and other species of animals and plants can also struggle for survival when sediment is introduced into their environment. Sediment causes turbidity (cloudiness of water) which in turn limits photosynthesis and plant growth. This can affect the entire aquatic food chain and interrupt reproduction processes. Suspended sediments can damage the gills of fish and severely reduce stream depth. Sedimentation of the channel can destroy or cover fish spawning grounds and can even limit the movement of fish upstream and downstream to get to these spawning grounds.

Urbanization usually has a negative impact on waterways and drainage channels. As storm water runoff and stream velocities increase, the potential for streambank erosion and scouring of the channel bottom is greatly increased. The eroding banks eventually slump, destroying naturally occurring undercuts that provide shade, cover and habitat for fish and other aquatic animals. This slumping process can be further exacerbated by clearing any existing riparian buffers. Streambank erosion also contributes to sediment deposition in the bottom of the channel which reduces channel depth. The waterway or drainage channel then tries to compensate for the reduction in channel depth by widening the channel. Once sediment has been introduced into the drainage system, it can remain in the system for a very long time. The following is a list of some long-term impacts associated with sediment deposition in stream channels:

- As sediment loads move through the drainage system they abrade the streambanks and destroy the food supply and habitat of aquatic organisms.
- Sandbars often increase in size, further restricting channel flow which usually results in increased flow velocities and accelerated streambank erosion.
- Reduction in channel depths leads to potentially less interchange of water, dissolved gases, and organic material between the water column and streambed.
- Macroinvertebrate diversity and numbers are decreased due to microhabitat change and degradation.
- Food supplies, spawning beds, and fish habitat is destroyed.

As shown in the previous discussion, development in one part of a watershed can have a significant impact and consequences on downstream areas of the watershed. However, when preservation and conservation measures are put into practice, nonpoint source pollution can be diminished and water quality can be maintained or even improved in some instances. Plant and animal communities can be protected and under ideal circumstances they can increase in number and diversity. Overall, water quality and the health of the entire watershed can be improved if storm water quality measures are properly installed and maintained.

Many of the previously discussed issues have rarely been addressed by local units of government when they regulate construction and land-disturbing activities. However, many communities are becoming more aware of these issues and are developing local programs to address erosion, sedimentation and storm water issues related to quantity and post-construction pollutants.

There is a wide variety of storm water quality measures that can be implemented on construction sites to prevent or minimize erosion and the associated environmental damages. These measures include both structural and nonstructural measures. Nonstructural measures are typically used to prevent or control erosion at its source. Structural measures on the other hand are designed to manage runoff and filter or allow for the settling of sediments suspended in storm water runoff. Erosion controls have a distinct advantage over sediment controls because they reduce the amount of sediment generated and transported off-site, thereby reducing the need for extensive sediment control measures. When erosion controls are used in conjunction with sediment controls, the size of the sediment control measures and associated maintenance may be reduced, resulting in decreased treatment costs.

Simple precautions such as identifying ecologically sensitive areas and marking them as “off limits” or protecting them from construction activity is one simple method of protecting the resource(s) from construction activity. This measure can be used to protect trees, native plants designated for preservation or use in the final landscaping, and animal habitats. It should be noted that erosion and soil loss is unavoidable during land-disturbing activities. While proper siting and design will help prevent areas prone to erosion from being developed, construction activities will invariably produce conditions where erosion will occur.

Pollutants that are associated with the post-construction land use can also be minimized by targeting specific pollutants and utilizing appropriate storm water quality measures. Post-construction impacts can also be reduced through planning projects that utilize natural site features and that incorporate principles that reduce impervious surfaces and the generation of pollutants.

A key element to storm water management that should be used on all projects is a storm water pollution prevention plan. This type of plan is very important in reducing the environmental impacts that are associated with active construction and post-construction land use. An effective storm water pollution prevention plan will incorporate design principles and an integrated system of structural and nonstructural storm water quality measures to minimize the adverse impacts to the watershed’s ecosystem.

Following chapters of this manual provide more detailed discussion in regard to storm water pollutants associated with urbanization and identify storm water quality measures that can be used to minimize the impacts of urbanization.

POLLUTANTS ASSOCIATED WITH URBANIZATION

The previous "Impacts of Urbanization" section discussed the impacts of urbanization and the pollutants that are associated with existing development, new development, and active construction sites. The pollutants associated with existing and new development are directly related to the land use. The primary pollutant associated with construction sites is sedimentation. Sediment is the number one pollutant by volume of surface waters in the United States. In addition to sediment, other pollutants associated with construction activities may include pesticides, petroleum products, nutrients, solid wastes, and various chemicals.

Other types of activities also have specific pollutants associated with them. These pollutants are generated from the operation and maintenance of roads, highways, and bridges as well as everyday activities and have a direct impact on the environment.

Roads, Highways, and Bridges

Pollutant sources associated with roads, highways, and bridges include both those generated during construction activity as well as those that are generated once the roadway becomes operational. Sources of pollutants associated with construction activities include sedimentation, on-site fuel storage and fueling operations, solid waste generation, chemicals associated with day-to-day operations, and nutrients from soil amendments used during site stabilization. Pollutants associated with operational activities include roadway maintenance operations (e.g., fertilizers, pesticides), solid waste generated from littering, and pollutants washed from the pavement (e.g., hydrocarbons, heavy metals, deicing agents).

Highway maintenance garages and rest areas can be major contributors to pollutant loadings. Maintenance garages are typically used for refueling and storage of sand and salt materials. If not properly managed, these substances can become potential pollutants. Rest areas can contribute to pollutant loadings because of their large, impervious parking areas and the high volume of vehicles that stop at these facilities.

General Sources (Including Household, Commercial, and Landscaping)

General sources of pollutants are those that are generated as the result of day-to-day activities by the public and businesses. Household activities, lawn and garden care, turfgrass management, vehicle use and maintenance, on-site sewage disposal systems, illegal discharges, and pet and domesticated animal wastes are the primary sources of pollutants associated with general day-to-day activities.

POLLUTANTS ASSOCIATED WITH URBANIZATION

Everyday household activities generate numerous pollutants that may affect water quality. Common household waste includes paints, solvents, lawn and garden care products, detergents and cleansers, and automotive products such as antifreeze and oil. A household product that contains hazardous substances becomes household hazardous waste once the consumer no longer has a use for the product and disposes of it. These pollutants are typically introduced into the environment due to ignorance on the part of the user or the lack of proper disposal options. The public unknowingly assumes that storm drains discharge into sanitary sewers and dump materials into storm drains under the assumption that treatment will occur at the sewage treatment plant. It is also commonplace for users to dump or dispose of many of these types of products directly onto the ground, not realizing that the materials can be carried to surface waters by runoff or pollute ground water if they are leached through the soil. Hazardous waste from households is not regulated as hazardous waste under federal and Indiana laws.

Landscaping activities are another common contributor to the pollutant loading of waterbodies within a watershed. For example, improper application or overapplication of fertilizers and pesticides can impair surface waters. In addition to surface water impairment, overapplication of nitrogen fertilizers can pollute ground water when it leaches through highly permeable soils. Improper disposal of lawn trimmings also leads to increased nutrient levels in storm water runoff. Lawn trimmings deposited in street gutters can be washed into drainage systems and result in elevated nutrient loadings of the receiving waterbody.

Litter and debris are significant contributors to the degradation of surface and ground water. Smaller materials are often carried by storm water runoff and deposited in surface waters. Improper disposal of larger items such as refrigerators and air conditioners can impair water quality through the release of fluids into surface water and ground water. These items degrade the aesthetic and recreational value of surface water and are a hazard to wildlife and aquatic organisms.

Domestic pet droppings have been found to be an important contributor of nonpoint source pollution. It has been shown that these waste materials can elevate fecal coliform and fecal streptococcal bacteria levels of waterbodies. This type of pollutant is most commonly associated with dogs. However, other urban animals such as domesticated or semi-wild ducks and Canadian geese can be major contributors to the nonpoint source pollution problem in areas where their populations are high.

Potential for impairment of surface waters and ground water can be greatly reduced through the proper handling, storage, management and disposal of the pollutants discussed above. The aforementioned techniques are discussed in the post-construction sections of this manual.

Typical Urban Pollutants

Pollutant	Contaminants	Sources	Effects	Impacts
Nutrients	• Phosphorous • Nitrogen	• Septic Systems • Agricultural runoff (fertilizers, animal waste) • Urban landscape runoff (fertilizers, detergents, plant debris)	Phosphorous is typically the primary nutrient of concern in freshwater systems as is nitrogen in saltwater systems. These nutrients encourage algal growth that can contribute to greater turbidity and lower dissolved oxygen concentrations. Lower dissolved oxygen can cause the release of other substances (pollutants) into the water column. Higher levels of nitrogen (nitrates) in groundwater are most commonly associated with agricultural practices and malfunctioning septic systems.	• Can limit recreational values (swimming, boating, fishing, and other uses) • Can reduce animal habitat • Potential contamination of water supplies
Solids	• Sediment (clean and contaminated) • Floatable wastes	• Construction sites • Agricultural lands • Disturbed and/or unvegetated lands including eroding stream banks • Floatable wastes are contributed from street litter and careless disposal practices	Increased turbidity and deposition of sediment.	• When deposited, clean sediment can decrease storage capacity to waterbodies, destroy benthic habitat (including animal nesting and spawning areas), and smother benthic organisms • Suspended solids can decrease transmission of light through water and interfere with animal respiration and digestion • Contaminated sediment acts as a reservoir for particulate forms of pollutants, such as organic matter, phosphorous, or metals that could be released later • These pollutants can be toxic or can decrease dissolve oxygen levels through the process of sediment oxygen demand (SOD) • Floatable wastes reduce the aesthetic value of the resource area and can cause clogging
Pathogens	• Bacteria • Viruses	• Animal waste (including pets and birds) • Failing Septic systems • Illicit sewage connections	Presence of bacteria and viral strains including fecal streptococcus and fecal coliform, in high numbers	• Can pose health risks • Can close or restrict use of shellfish beds and beach areas
Metals	• Heavy metals including lead, copper, cadmium, zinc, mercury, and chromium	• Industrial activities and waste • Illicit sewage connections • Automobile wear, exhaust and fluid leaks • Atmospheric deposition	Increased toxicity of runoff and availability of metals that can enter into the food chain.	• Metals can accumulate in certain animal tissues that could be ingested by humans or other animals • Can affect sensitive animal species, plants and fisheries

Typical Urban Pollutants (continued)

Hydrocarbons	• Oil and grease • Petroleum-based substances • Polycyclic aromatic hydrocarbons (PAHs)	• Parking lots and roadways • Oil Leaks • Auto Emissions • Illicit sewage connections • Illegal dumping of waste oil	Degraded appearance of water surfaces; limiting water and air interactions (lowered dissolved oxygen).	• Toxic to sensitive animal species • Degrades fisheries habitats
Toxic Organics	• Pesticides • Polychlorinated biphenyls (PCBs)	• Indoor and outdoor use • Industrial activities • Illicit sewage connections	Increased toxicity to sensitive animal species and fishery resources.	• Causes loss of sensitive animal species and fishery resources
Acids	• Nitrates (NO_3) • Sulfides (SO_2)	• Incomplete combustion process coupled with atmospheric reactions (acid rain)	Increased toxicity to sensitive animal species and fishery resources.	• Causes loss of sensitive animal species and fishery resources
Humic Substances	• Plant materials such as grass clippings and leaves	• Urban and suburban landscapes	Increased loading into waterbodies of organic materials that require oxygen to decompose; lowered dissolved oxygen levels can cause the release of other substances (pollutants) into the water column.	• Degrades fishery resources • Reduces fish populations
Salt	• Sodium • Chloride	• Road salting procedures	Increased toxicity to organisms, reduction of fishery resources, and increased levels of sodium and chlorides in surface and ground waters. Could stress plant species' respiration processes through their effect on soil structure and can cause loss of other compounds necessary for plant viability.	• Causes loss of sensitive animal species, plant species, and fishery resources • Contaminates surface and ground waters

Source: Adapted from Phillips, N. 1992. Decisionmaker's Stormwater Handbook. Terrene Institute, Washington, DC

Construction Site Assessment & Planning

Above photo by United States Department of Agriculture,
Natural Resources Conservation Service, Iowa 2000, Lynn Betts

INTRODUCTION TO SITE ASSESSMENT & PLANNING

Construction site assessment and planning is an important part of any construction project. Prior to planning, designing, or laying out a project, it is important for the plan designer to have knowledge of the project site and adjacent areas. To accomplish this objective it is necessary to collect information about the proposed project site. This information can then be used by the plan designer to make informative decisions in regard to project planning, design, and layout. In addition, it allows the plan designer to develop a set of construction plans that will allow for development of the project in an efficient, cost-effective, and environmentally sensitive manner.

Construction site assessment and planning usually involves three steps. Step one is site assessment and data collection. The second step is to analyze the collected data. The third and final step is to begin incorporating this information into a preliminary concept and design.

SITE ASSESSMENT & DATA COLLECTION

Site assessment and data collection is the first step in the planning, design, and layout of any construction project. This step involves collection of resource information applicable to the project site. Information can be obtained through research of existing publications, maps, studies, and other resources. In addition to obtaining information through research of existing documents, it is important to walk the project site to obtain a visual appreciation of the site and site features.

Taking good notes and documenting information is very important in this phase of site assessment and planning. Collected information can be documented in narrative or graphical format. Information that is collected in graphical format such as maps should be of the same scale whenever feasible. This allows the plan designer to overlay different site maps and compare various resources and data at a quick glance.

Key information that should be collected includes but is not limited to the following items.

Vegetative Cover

The type and amount of vegetative cover is one of the easiest forms of data to collect for a project site. This information gives plan designers an understanding of the stability of the site and its current susceptibility to erosion.

Vegetative cover can be documented in narrative and/or graphical format. Graphical documentation should be on a map or overlay and at a minimum include the delineation and identification of existing vegetation such as grass, shrubs, trees, groupings or clusters of trees, unique vegetation, and so on. If the site is farmed, documentation should identify the crop and/or crop residue at the site. Narrative documentation should include the quality and condition of the vegetation, its ecological and aesthetical value, and its potential for use in the planning, design, and layout of the proposed project.

Soils Information

Soils information is another key component in the planning, design and layout of construction projects. Soil types in conjunction with site topography can provide valuable information in determining areas with a high potential for erosion. Soils data can also be used in the selection, sizing, design, and placement of storm water management measures.

Soils information can generally be obtained from the U.S. Department of Agriculture's Natural Resources Conservation Service county soil surveys which are available through local county soil and water conservation district offices. Soils data can also be obtained through the services of private soils consultants or firms who prepare geotechnical reports.

Soils data should be documented in both graphical and narrative form. Soil types should be delineated directly onto an aerial photograph or an overlay of the same scale as the topographic map(s) for the project site. This facilitates the comparison of soil types and their relationship with the topography of the site.

Data collection should also include information pertaining to critical areas or features such as steep slopes (see Topographical Information below), rock outcroppings, seepage zones, and any other unique or noteworthy landscape features.

Soils data should be documented in narrative form as well as graphical form. The narrative should describe the respective soil types including their physical characteristics and their limitations and/or hazards for the intended land use. Soils information that is most commonly collected and useful in the design and layout of a project includes but is not limited to depth of topsoil, soil texture and particle size, infiltration rate, permeability, depth to limiting layers (i.e., bedrock, fragipan, glacial till), shrink-swell potential, low strength, susceptibility to erosion, ponding, and depth to the seasonal water table.

Topographical Information

Site topography is critical to project planning, design and layout. Topographic maps provide useful information that the plan designer can use to determine drainage patterns, slope gradient and length, and the location of ecologically sensitive features such as waterbodies.

Topographic elevations for a project site should be documented in graphical form. Topographic information can be obtained from United States Geological Survey quadrangle maps (these may not provide the detail appropriate for site planning) or the data can be collected by conducting an on-site topographic survey. If the data is collected through an on-site survey, the topographic map should show existing contour elevations at intervals that are appropriate to determine drainage patterns and slope of the land. One foot and five foot contour intervals are the most common intervals used when making an on-site topographic survey. However, in areas with steep terrain it may be acceptable to use an interval of ten feet

Hydrological Information

Hydrologic features are critical in planning, designing, and laying out a construction project. It is extremely important to identify, delineate, and record all depressional areas such as ponds, lakes and wetlands and conveyance systems, including swales, ditches, streams, creeks, rivers, and areas of concentrated flow that are on or adjacent to the project site. This information allows the plan designer to determine drainage patterns, evaluate the condition of various drainage features, determine if they can be incorporated into the project, and select storm water management measures to protect ecologically sensitive areas.

Streams, ponds, and other water features located downstream from the project site should be surveyed to determine their carrying capacity and sensitivity to sedimentation and flooding. It is important to consider their potential for channel or shoreline erosion as a result of increased storm water runoff volumes, velocities, and peak discharge flows.

Many Indiana soils have a seasonal high water table. Over the years, landowners have installed numerous subsurface tile drainage systems to manage the seasonal water table for agricultural production. Interconnected subsurface drainage systems frequently cover several parcels of farmland. Breakage or disruption of a subsurface drainage system often affects the drainage on adjacent properties and can result in ponding or flooding of upstream areas. Therefore, when land is converted from agricultural uses to urban uses, it is extremely important to identify and delineate these subsurface drainage systems so that they can be integrated into the planning process. Locating subsurface drainage tile is generally more difficult and requires on-site exploration. Some landowners may have a written record or graphical plans showing the location of subsurface drain tiles on their properties. In extremely rare instances, local soil and water conservation districts may have aerial photographs showing the location of subsurface drain tiles or written records/graphical plans showing drain tile locations.

Hydrologic data of a project site should be documented in graphic and narrative form. Major conveyance systems and waterbodies can generally be identified using U.S. Geological Survey quadrangle maps and U.S. Fish and Wildlife Service National Wetlands Inventory maps. Smaller features may require on-site visual inspection and documentation.

Hydrologic features should be delineated on a topographical map or overlay. All locations where storm water runoff may enter, cross, and/or exit the project site should be clearly identified. Areas where storm water runoff may concentrate on the project site should also be identified on the map or overlay.

Once again, hydrologic features should be documented in narrative form as well as graphical form. The narrative should describe the condition of the drainage feature, its ecological value, its aesthetic value to the project, and its potential for use in the project's overall storm water drainage and management system.

Adjacent Areas

Site assessment and data collection should include an evaluation of adjacent properties and their respective land uses. This information provides the plan designer with valuable information that can be used to determine the effects that storm water runoff and pollutants associated with upstream watershed land uses (e.g., single-family residential, multi-family residential, commercial, industrial, agricultural, woodland, etc.) might have on the proposed project site. It also aids in projecting what impacts a project might have on downstream watersheds and sensitive areas.

Features of significance that should be documented and evaluated include but are not limited to rivers, streams, creeks, lakes, ponds, wetlands, wooded areas, roads, culverts, houses and other structures. Site assessment should include documenting the potential for sediment deposition and damage to adjacent properties as a result of sheet and rill erosion from the project site once construction begins.

Adjacent land uses and site features should be identified and delineated on a site map or overlay. If a particularly important feature(s) is located a significant distance outside the limits of the project site, the feature should be documented in a detailed note on the site map or a smaller scale map should be used to clearly identify the location and specific details of the feature.

Utility & Highway Corridors

Utility and highway corridors and easements on or adjacent to a construction project should be identified and delineated on a project site map. This information is useful when planning, designing, and laying out a project and developing a construction plan for the project.

Existing Infrastructure & Potential Problem Areas

A commonly overlooked aspect of site assessment and data collection is the identification of past activities and potential problem areas associated with the project site. These issues can often delay or even stop a project if they are overlooked.

All existing structures and infrastructure associated with a project site should be identified on a project map. If buildings and other structures are present and are to be demolished, an assessment of the building materials and contents should be characterized and documented in the narrative.

Some of the more common areas of concern that should be identified on a site map or in the project narrative include abandoned wells, underground storage tanks, improper disposal of trash and debris, subsurface drainage tile, buried waste materials, and contaminated soils.

Natural, Historical & Archeological Features

Natural, historical, and archeological features can also delay or stop a project if not addressed in the planning, design and layout of a project. This element of site assessment and data collection should include features that may be impacted by the overall project, from initial construction through the final land use.

The project site should be assessed for the presence of any historical or archeological features. This includes but is not limited to historic buildings/features, burial sites, and artifacts. Common artifacts include spear points, arrowheads, knives, chipped or broken stone debris, ground stone axes, grinding stones, mortars and pestles, awls, gouges, pottery, clothing and ornamental pins, decorative items and ornaments, scraping tools, hammerstones, bone fishhooks, stone perforators, and beads. For more information regarding historical and archeological issues, please contact the Indiana Department of Natural Resources, Division of Historic Preservation and Archeology.

Natural features such as bodies of water, floodplains, wetlands, sinkholes, unique habitat, and presence of endangered or threatened species should be identified on a site plan map or in the project narrative.

Regulations

While is it still early in the planning, design and layout process and many decisions still need to be made, it is not too early to start evaluating what permits may be needed for the project.

Regulatory requirements can influence land use and project layout decisions. Often, a project's design or layout can be modified or adjusted to avoid the need for a specific permit or to meet specific regulatory requirements. Therefore, site assessment and data collection should include documentation identifying the need or potential need for local, state, and federal regulatory permits. The types of permits needed will be dependent on the nature and scope of the project.

ANALYSIS OF COLLECTED DATA

As the site assessment and data collection phase nears completion, a picture of the project site's potential and limitations will begin to emerge. The next step in the planning, design, and layout process is to analyze, interpret, and compare the site resource information and data that has been collected. As the data is analyzed it may be necessary to conduct additional research on one or more items associated with the project or to return to the site to make additional field observations.

The remainder of this section of the manual provides insight into the decision-making process and gives guidance in the review and interpretation of the data that was collected during the site assessment and data collection process.

Vegetative Cover

Analysis of vegetative cover should begin by identifying vegetation that is of high quality and value and may enhance the aesthetics of the overall project. Vegetative cover or features that may be of particular interest include but are not limited to unique habitat areas and riparian corridors. Trees in particular can be a very valuable asset and can significantly increase the aesthetics and salability of lots within a project. Some communities in Indiana have requirements to preserve trees when land is developed. When evaluating and assessing trees, it is often times very beneficial to consult a professional forester. They can identify which trees will add the greatest value to a project and identify which trees are diseased or may not survive construction activities.

Soils Information

As soils information is evaluated, it is often beneficial to group soils with similar characteristics. For example, grouping of soils with similar seasonal water table depths can help determine which areas of a residential project are best suited for home construction verses which areas might be used for common areas or greenways. Grouping of seasonal water table depths can also provide insight into which soils have limitations for roads and streets because of frost action.

Part of the data analysis process should include an understanding of state and local regulatory agency on-site waste disposal regulations. While grouping of soils with rapid permeability or slow permeability can help determine overall areas best suited for on-site sewage treatment disposal systems, it is generally recommended that specific on-site soil evaluations be performed on each individual on-site waste disposal system site to determine the soil's adequacy to support such a system.

In regard to water quality, soil erodibility is one of the first soil characteristics to review and evaluate. Soil erodibility will help determine the location and size of storm water management and treatment measures. For example, soils with a high percentage of mineral particles that are 0.02 mm or smaller in size will stay in suspension in the water column for long periods of time and will be difficult to remove via basic storm water quality treatment measures. In fact, these small soil particles often require extensive sediment basin design in conjunction with other storm water management and treatment measures. Land grading can also compound this effect because it typically results in the mixing of surface soil material with higher clay content subsoil materials.

Topographical Information

Slope gradient and length are the two primary factors to consider when analyzing and interpreting topographic information. This information is critical when designing and laying out the project because it will ultimately affect the decisions that will need to be made when selecting appropriate construction and post-construction water quality management and treatment measures. For example, decisions made in regard to areas of land disturbance and the removal of vegetation on steeper slope gradients will affect the selection, design, and location of storm water management and treatment measures (i.e., as unvegetated slope gradients increase the size and cost of the storm water management and treatment measures will also increase).

For ease of interpretation and comparison of data, slope gradients are typically grouped into the following four general ranges.

- 0 to 2 percent
- 2 to 6 percent
- 6 to 12 percent
- Over 12 percent

These ranges or groupings can be used to categorize various topographic limitations such as soil erodibility. A slope range of zero to two percent usually has a low erosion hazard whereas a two to six percent slope range has a low to moderate erosion hazard. A six to 12 percent slope range has a moderate to high erosion hazard, and slopes over 12 percent have a severe erosion hazard.

Slope length is another aspect that is important in identification of a site's erodibility hazard. As slope length increases within a slope gradient range, the potential for erosion increases exponentially. As a general rule, the erosion hazard will become critical if slope lengths exceed the following lengths within each respective slope range.

- 0 to 2 percent 300 feet
- 2 to 6 percent 200 feet
- 6 to 12 percent 100 feet
- Over 12 percent 50 feet

Hydrological Information

Natural drainage patterns and other hydrologic features exist on the land and include overland flow, conveyance channels, swales, depressions, and other watercourses and natural waterbodies. It is important to evaluate these features for their potential to be incorporated into the project's overall storm water management system.

Understanding how storm water flows onto and off a project site is critical to project design and layout. Evaluation of hydrologic data often begins by examining areas up slope of the project site and determining the volume and velocity of storm water that will enter the project area. This information will be used to determine the type, location, and design of storm water measures that will be needed to manage storm water entering and/or flowing across the project site.

When subsurface tile drainage systems are encountered on a project site, it is important to evaluate the size of the drain tiles and the watershed area that they drain. Subsurface drainage systems should be evaluated to determine if rerouting of the system is necessary to maintain drainage of adjacent properties and prevent upstream ponding/flooding problems. Subsurface drain tile should not be used as storm drains. They are typically not designed for this purpose and their capacity is often exceeded, resulting in failure of the drainage system.

Another important aspect of evaluating hydrologic data is the assessment of existing construction and post-construction storm water runoff volumes, velocities and peak flow discharges from the project site, and determining what impacts they will have on downstream hydrologic features and land areas. This evaluation should include an assessment of potential streambank erosion in the downstream receiving channel(s). It should include an evaluation of the potential for sediment pollution from sheet and rill erosion. Once project planning, design and layout begins, it may be necessary to recalculate storm water discharge volumes and peak flows to assess the impact those decisions will have on off-site features such as channels and culverts. Once again, this information will provide insight into identifying the type, location, and design of storm water measures that will be needed to minimize off-site resource impacts to downstream areas.

Adjacent Areas

Data that has been collected in regard to adjacent properties should be evaluated to determine what effect adjoining land uses might have on the proposed project. Evaluate if these land uses will require the installation of storm water management measures on the project site to manage runoff quantity and treat storm water runoff and pollutants associated with the upstream land use(s). Also evaluate what effects storm water runoff and potential pollutants from the proposed project might have on adjoining properties located down slope from the project site.

Utility & Highway Corridors

Utility and highway corridor data should be assessed to determine how the proposed project's infrastructure might be tied into these corridors or whether or not these corridors can be incorporated into the overall project design. Evaluate what effect these land uses might have on the proposed project.

Existing Infrastructure & Potential Problem Areas

Potential problem areas identified during the site assessment and data collection phase should be reviewed and evaluated to determine what effect they will have on the project. Assess data to determine if any remedial actions will be needed to reclaim or restore areas of concern on the proposed project site.

Natural, Historical and Archeological Features

Proper analysis of natural, historical, and archeological data is critical in preventing the delay of a project. Identification of many of these features often requires the developer to apply for local, state, or federal permits. Therefore, this data should be analyzed to determine what permits might be needed.

Regulations

As the data for the project is reviewed and analyzed, the designer should keep in mind the permits that may be required for the project.

Permit application processes can often delay construction projects. During this phase of planning, it is important to identify the permits that will be required. If feasible and not dependent on design decisions, the permitting process should begin. This may include actual submittal of permits or, at a minimum, a dialogue with the regulatory agency to identify specific information that will be required to obtain a permit.

PLAN DEVELOPMENT & PROJECT LAYOUT

The final step in construction site planning and assessment is to incorporate the collected data and information into the overall project plan, design, and layout. This section will provide a broad overview and insight into that process. Later sections of the manual will go into much more detail in planning, designing, and laying out a project, including the selection of appropriate storm water measures.

Vegetative Cover

Vegetative cover is probably the most important factor in terms of preventing erosion. Vegetation is also valuable in its ability to act as a buffer and filter pollutants from storm water runoff. Therefore, every effort should be made to preserve and incorporate existing vegetation into the proposed project.

In the analysis of collected data phase of the construction site planning and assessment process the designer has identified areas of vegetation that are of value and should be preserved on the project site. As part of the planning, design, and layout process, these areas should be delineated on the project's construction plans. Delineate major areas or groupings of trees, grass, cultivated land, etc. on the overall project site. Delineate areas that are designated for protection and specify how these areas are to be protected (i.e., a physical barrier such as a fence).

Identify areas that have a dense vegetative cover that can be used to provide effective erosion control as long as the area is not graded, or areas where existing vegetation can be used to filter storm water runoff and allow suspended soil particles to settle out. Identifying vegetative cover that is suitable for use as a vegetative filter also allows the plan designer to substitute these filters for other sediment trapping measures which in turn will reduce the overall cost of a project.

In situations where existing vegetation cannot be saved or where there is no vegetation on-site, consider staging construction activities. Staging of construction activities involves stabilizing part of the project site before disturbing another section of the site. This minimizes the length of time that soil is exposed to the erosive forces of wind and water.

Temporary seeding and mulching can be used to stabilize unvegetated areas that would otherwise be exposed for long periods of time, thus reducing the erosion hazard.

Vegetated riparian buffers located adjacent to waterbodies and other sensitive areas are an effective means of protecting these features from storm water runoff pollutants. Existing riparian buffers should be delineated or identified on the construction plans and the plans should identify measures to protect or, where necessary, enhance or re-establish existing buffers.

Soils Information

Soils generally have the greatest impact on project planning, design and layout. Their inherent properties, limitations, and hazards can literally dictate the layout of building lots/pads, roads and streets, storm sewers, on-site sewage disposal facilities (where applicable), and other project infrastructure. Soil characteristics such as depth to bedrock, depth to the seasonal water table, permeability, shrink-swell potential, texture, and erodibility need to be evaluated and factored into the design and layout of the project.

Soils data must be taken into account when evaluating, selecting, locating, and designing storm water management measures that will be used to manage storm water runoff during active construction. Areas of highly erodible soils should be identified on the construction plans and the plans should identify management measures that can be used to minimize erosion on these areas.

Soils data must also be taken into account when selecting storm water management measures for post-construction activities. For example, infiltration measures will be ineffective in soils that have a high clay content or soils that have an extremely high gravel content. The use of filtration and infiltration measures may be severely restricted or impractical in soils with a seasonal high water table unless there is some way to artificially lower the water table.

Project planning, design, and layout should take into account critical areas such as steep slopes (see Topographical Information below), rock outcropping, seepage zones, and any unique or noteworthy landscape features that were identified in the site assessment and data collection phase. Many critical area features can impact the layout of roads and streets, building lots/pads, and on-site sewage disposal facilities. Often, critical area features can be incorporated into common areas and greenways within the development and can actually add aesthetic value to the project.

Topographical Information

Topographic information that has been collected should be used to delineate areas with similar slope gradients. Slope gradients are typically grouped into the four general ranges of zero to two percent, two to six percent, six to 12 percent, and 12 percent or greater. Many building/construction parameters and storm water management measure design specifications are based on these slope gradient ranges.

Using collected topographic information, delineate all major watershed boundaries that are associated with the project site. Often, these watershed boundaries will extend up slope or down slope of the actual project site boundaries. Delineation of the watersheds will help identify the direction of surface water flow. If a delineated watershed exceeds five acres, the plan designer should subdivide the watershed into smaller watersheds. Smaller watersheds are more manageable units when predicting storm water runoff volumes and selecting storm water management measures. It is also important to keep in mind that many storm water management measures have design and application parameters well under the five acre threshold. In fact, the design and application of many measures are typically for one or two acres.

Watershed boundaries will be used many times throughout the planning, design, and layout process. For example, they will be used when calculating storm water runoff volumes, assessing erosion potential, estimating sediment yields, and selecting appropriate storm water management measures.

Hydrological Information

It is critical that the plan designer understands how water flows onto and off of a project site. Where possible, natural drainage systems should be incorporated into the project's design and layout and used to convey storm water runoff through and from the project site.

Using information and data collected on upstream watersheds, analyze the volume and velocity of storm water runoff from adjacent areas that may enter the project site. Evaluate and identify storm water management runoff measures that need to be installed or constructed on the project site to divert the storm water run-on away from construction zones and minimize impacts to the construction project.

Using the hydrologic data that has been collected and the watershed areas that have been delineated, calculate storm water runoff volumes, velocities and peak flows associated with existing site conditions, and begin laying out and designing the project site's drainage system. As drainage system planning, design, and layout decisions are made, it may be necessary to recalculate discharge volumes and peak flow discharges and assess their impact on off-site features such as channels and culverts.

The next step is to evaluate and determine what impact the project's proposed drainage system will have on downstream waterbodies. Storm water management measures must be incorporated into the construction plans to ensure that there is little or no impact to the carrying capacity and sensitivity to sedimentation and flooding of the downstream waterbodies.

In situations where subsurface drainage tile have been identified on the project site, tile locations should be marked on the construction plans. Where applicable, rerouting of these tiles should be identified and the new tile location shown on the plans.

Adjacent Areas

Special attention should be given to planning a project when there is potential for the project to impact adjoining properties and ecologically sensitive features. It is important to address downstream discharge points, the potential for sediment pollution, and/or downstream channel erosion and deposition and the effects they can have on downstream waterbodies. This includes the impacts that sheet and rill erosion could potentially have on adjoining properties located downstream of the project site. Appropriate storm water management measures must be identified and built into the construction project to minimize impacts to the previously identified downstream land use(s) and waterbodies.

Utility & Highway Corridors

Lay out lots/building pads, streets and roads, and on-site sewage disposal systems (if applicable) so that they do not interfere with existing utility and highway corridors. Utility corridors must be kept free of obstructions, especially if they require regular maintenance activities or if they present a safety hazard.

Identify specific storm water management measures that need to be installed on the proposed project site to address runoff from these land uses. For example, it may be necessary to incorporate storm water measures into the proposed project to provide for the runoff from roads and impervious surfaces.

As the project layout and design begins to take shape, tie proposed utilities, utility easements, and roads and streets into existing utility and highway corridors. Identify storm water measures needed to protect these corridors from erosion, sedimentation, and construction traffic. In addition to protecting the integrity of the corridors, it may be necessary to incorporate signage or safety fence to notify or restrict construction operations in these highly dangerous areas.

Existing Infrastructure & Potential Problem Areas

Identify and incorporate into the construction plans appropriate or remedial measures that will address potential problem areas that were identified in the site assessment and data collection phase. In situations where remedial action is delayed or it is impossible to correct or eliminate problem areas, allow for provisions to work around the area(s).

Natural, Historical & Archeological Features

Natural, historical and archeological features identified in the site assessment and data collection phase should be incorporated into the project plan, design, and layout. These features often can be incorporated as an aesthetic element in the design of common areas or greenways. Construction plans should include the identification of measures that must be installed to protect culturally and environmentally sensitive natural, historical, or archeological areas from construction equipment and construction activities.

In situations requiring permits, the permit application process can take anywhere from days to weeks or months. Therefore, the permit application process should be started as soon as possible.

Regulations

Permit application processes can often delay construction projects. As project decisions are made, the designer should evaluate each decision and how these decisions will affect the need for permits. This will require knowledge of local, state, and federal regulatory requirements. Part of this process may require additional research or dialogue with the appropriate regulatory agency. If permits are required, start the permit application process as soon as possible. Where feasible, consider adjusting the project design and layout to eliminate the need for the permit(s).

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Construction Plans

Above photo source: Georgia Stormwater Management Manual, 2001

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INTRODUCTION TO CONSTRUCTION PLANS

Construction plans are a representation of a project site and all activities that will be associated with the overall construction of the project. More specifically, a construction plan is a document that explains an entire construction project in detail including details of layout, design, and operational procedures.

Construction plans are a very important part of any construction project. They give contractors and subcontractors a visual of the proposed project, provide an orderly timeline and construction sequence, provide detailed standards and specifications, and give guidance in the day-to-day construction activities associated with the project.

This chapter gives a general overview of the purpose and contents of construction plans.

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Purpose

The purpose of a construction plan is to provide contractors and subcontractors with sufficient information to construct a project in the most efficient and cost-effective manner possible. To meet these objectives, construction plans must contain sufficient detail to adequately portray the layout of the project; identify areas of concern and provide measures to protect or overcome the identified concerns; provide an orderly timeline and construction sequence; provide detailed standards and specifications for various aspects of the project; provide a list of construction materials required for the project; and give appropriate guidance in the day-to-day construction process.

Content

The information in this chapter provides a general overview of the contents of a construction plan. Additional information may be required by regulatory authorities based on local, state, and federal regulations. It is the responsibility of the plan designer to identify specific requirements associated with applicable regulations and include that information in the construction plan.

In general, a construction plan should include an array of information that clearly depicts the overall project, including all construction activities and storm water management measures associated with the project. It should include but is not limited to a narrative about the project, project location information, predevelopment site conditions, a final project site layout plan, a drainage plan, a grading plan, and a storm water pollution prevention plan.

Construction Plan Index

In addition to the above, construction plans should include a plan index identifying the items that are contained in the plan and a reference as to where each item is located in the plan. An index is a key element to any construction plan and can be very useful to individuals using the plans as well as regulatory agencies who review the plans for compliance with local, state, and federal regulations.

The following sections in this chapter provide a brief overview of the key elements in a construction plan and their respective contents.

Plan Narrative

A plan narrative should be the first major element of any construction plan. A plan narrative is a written statement that describes the overall project. It should provide a clear understanding of the proposed project and can include a variety of items with the intent to inform, explain, and clarify issues associated with the site.

Construction plans require a variety of items. Some items and activities associated with a project may be portrayed more accurately in graphical or tabular form and located in a specific section of the construction plan while others may be adequately represented in the narrative. Therefore, there is no set standard for what should be included in a plan narrative.

Generally, a construction plan narrative will include items that do not have to be displayed in relation to other activities that will occur on the construction site. A few examples of items that could be discussed in the narrative section include a legal description of the project site, site characteristics, an explanation of expected pollutants associated with the project, construction schedules, operational procedures, and a general description of proposed storm water quality measures. Typically these items are not found on construction plan details sheets.

Project Location

Identifying a project's location is another key element of any construction plan. Typically, this information is provided as a graphical representation of the site as well as in narrative format.

Graphical identification of a project site is typically done by providing a vicinity map that depicts the site in relation to other identifiable areas in the city or county. Vicinity maps should contain sufficient detail so that someone unfamiliar with the area can locate the project site. U.S. Geological Survey topographic maps, county road maps, city street maps, custom drawn maps, etc. are acceptable types of vicinity maps as long as they adequately depict the site's location. Vicinity maps are typically placed on the cover sheet of the construction plan.

Narrative depiction of a project site is generally done by identifying the project site to the nearest quarter section, including township and range coordinates and civil township. Latitude and longitude coordinates identifying the approximate center point of the project should also be provided. Latitude and longitude coordinates can be obtained from U.S. Geological Survey topographic maps or from various Web sites.

Predevelopment – Existing Site Conditions

All construction plans should provide a representation of the project site that includes predevelopment conditions and existing site features. This information is extremely valuable in developing subsequent components of the construction plan. This element of a construction plan typically includes but is not limited to the following items.

Existing Vegetative Cover

A predevelopment plan should delineate and identify the existing types of vegetative cover such as grass, trees, brush, and so on. It is not necessary to identify individual species of plants.

Identification of vegetative cover serves two primary functions. First, it provides the plan designer needed data when making storm water calculations for the project's storm water management system. Second, it provides a basis for evaluating the location, appropriateness, and adequacy of proposed storm water quality measures.

Adjacent Land Use

Predevelopment plans should clearly identify the land use of the upstream watershed and other areas adjacent to the project site. This information provides a basis for evaluating the effects that storm water runoff and pollutants associated with upstream watershed land use (e.g., single-family residential, multi-family residential, commercial, industrial, agricultural, woodland, etc.) might have on the proposed project site. It also aids in projecting what impacts a project might have on downstream watersheds and sensitive areas.

Site Topography

Existing site topography is critical in evaluating where storm water discharges will flow off-site and can be used in conjunction with final site topography information to evaluate areas and quantities of soil cut and fill. Existing site topography also provides a basis for evaluating the location, appropriateness, and adequacy of proposed storm water quality measures.

Site topography is typically depicted through the use of topographic contour lines or spot elevations. When using spot elevations, there should be a sufficient number of points to be able to visualize the site topography. To properly analyze and evaluate this information, all topographic lines, elevation numbers, and spot elevations must be legible.

In the case of linear projects such as highways, roads, utility lines, etc., cross-sectional views and plan and profile views of the project are generally acceptable since it is often difficult to show topographic contour lines or spot elevations for these kinds of projects.

Soils Information

Soils information should be an integral part of a project site's construction plans. The plans should contain a soils map and corresponding soils map unit legend that delineates and identifies the soil types located on the project site. A legible copy of the appropriate soils map taken from the U.S. Department of Agriculture Natural Resources Conservation Service county soil survey in the county where the project site is located is sufficient. Soils maps prepared by a professional soil scientist, soil boring logs, and geotechnical soils reports are also acceptable.

In addition to a soils map, the construction plans should include a discussion of the soil characteristics, limitations, and hazards associated with the project site and the measures that will be integrated into the project to overcome or minimize any adverse soil conditions. For example, if on-site sewage disposal systems are proposed for use on a single-family residential project site, the plan designer should provide information in regard to soil limitations such as a seasonal high water table, slow permeability, poor filtering qualities of the soil, and so on. The plan designer should also identify measures that can be integrated into the project to minimize the respective soil limitations. In the above scenario, the plan designer might specify that perimeter subsurface drainage tile are required to lower the seasonal high water table and minimize the wetness limitation or that a modified on-site sewage disposal system must be installed to compensate for the slow permeability or poor filtering qualities of the soil.

Soil properties also need to be considered when selecting post-construction storm water quality measures for a site. Many structural post-construction measures are designed based on the soil's natural ability to allow infiltration of storm water. If infiltration is too rapid, there is little time for removal of pollutants and storm water treatment. If infiltration is too slow, there is potential for the measure to fail.

Wetlands, Lakes, and Watercourses

Wetlands, lakes, and watercourses that are on or adjacent to a project site should be identified on the predevelopment plan. This information is important in evaluating proposed storm water measures and ensuring that they are appropriate and adequate to minimize water quality impacts to natural, sensitive areas both on and adjacent to the project site. Also, identification of nearby watercourses and waterbodies may place additional importance on sediment control in a particular area of the project.

Potential Discharges to Ground Water

Areas of potential ground water recharge should be clearly identified and located in the construction plans. These areas can have a profound effect on ground water quality.

Existing features such as sinkholes and abandoned, uncapped wells can serve as a direct conduit for contaminated surface water to enter ground water. Therefore, it is extremely important to protect these areas if they occur on or downstream of a project site. In addition, storm water infiltration measures such as drywells, which may be planned as part of the project, could have a potential impact on ground water quality.

Once identified, adequate measures should be incorporated into the construction plans to prevent storm water runoff from entering ground water recharge areas or, at the very least, provide for some type of storm water pretreatment before it is allowed to enter ground water. For example, abandoned wells should be properly capped.

Final Project Site Layout

A final project site layout plan is an integral part of a construction plan. It provides a visual representation of what the project will look like after construction is completed.

Typically, a final project site layout plan identifies the location of lot boundaries, lot numbers, utilities, and streets including street names if available. It also identifies common areas such as community parks and greenways. On smaller residential projects and on commercial and industrial projects, the final project site layout plan may also show the proposed location of structures and parking areas.

Drainage Plan

Drainage plans are one of the most important elements of any construction plan. A drainage plan identifies how storm water will be managed on a particular project and determines what effect the project's storm water management system will have on adjoining properties and infrastructure. Elements of a drainage plan typically include but are not limited to the following items.

Site Topography

Drainage patterns and location of the drainage system is generally determined based on the topography of the site. Site topography is typically depicted through the use of topographic contour lines or spot elevations. When using spot elevations, there should be a sufficient number of points to be able to visualize the site topography. To properly analyze and evaluate this information, all topographic lines, elevation numbers, and spot elevations must be legible.

As noted earlier in this chapter, existing site topography is critical in evaluating where storm water discharges will flow off-site. Similarly, final site topography is critical in evaluating where post-construction storm water discharges will flow off-site and the location, appropriateness, and adequacy of proposed storm water measures. Therefore, it is important that a drainage plan show both existing and proposed site topography.

Existing site topography is typically depicted using a dashed or solid contour line, whereas final site topography is generally depicted using topographic contour lines that have a darker line density or through the use of spot elevations. In the case of linear projects such as highways, roads, utility lines, etc., cross-sectional views and plan and profile views of the project are generally acceptable since it is often difficult to show topographic contour lines or spot elevations for these kinds of projects.

Location of Storm Water Drainage System

Nearly every drainage plan identifies the location of all proposed storm water drainage systems such as swales, drainage channels, piping, culverts, etc. associated with a project and indicates the respective sizes, dimensions, and construction details of the various drainage system components. Drainage plans should also identify all points where storm water discharges will leave the project site. If the plan's topographic contour lines or the storm water drainage system does not clearly define off-site discharge points, these points should be identified with a note(s) placed on the plan.

Storm Water Calculations

Most drainage plans include design data, such as pipe sizes and discharge rates, for sizing of storm water management systems. In addition, drainage plans often include sizing and trap efficiency data for sediment traps, sediment basins, open channels, grassed swales, and so on.

Drainage plan design data is generally given for both preconstruction and post-construction conditions. This is done to show the overall impact the project may have in relation to storm water runoff quantities and velocities and potential impacts on adjoining land uses.

Drainage plan data is generally arrived at by calculating the size of the drainage area for each structure or measure and a specific-sized storm event. The two most commonly used storm events are the 10-year frequency, 24-hour duration event and the 100-year frequency, 24-hour duration event.

Storm water calculations can be done via several methods. Some of the more common and acceptable methods are the rational method, Technical Release Numbers 55 and 20.

Receiving Waters

Drainage plans should identify all named streams or other waterbodies that may potentially receive storm water runoff from the project site. If the discharge is to a municipal storm sewer system, the plan should identify the owner of the storm drain system as well as the ultimate receiving water for the storm drain system.

Floodplains

Floodplains, floodways, and floodway fringes that are located on a project site should be delineated on the drainage plans. In situations where there is no floodplain, floodway, or floodway fringe on the project site but one exists within close proximity of the project area, the construction plans should show the feature(s) delineated on the drainage plan. At a minimum, include a discussion of their existence in the narrative or on the plans.

When there are no floodplains, floodways, or floodway fringes associated with the construction project, a note should be placed either on the graphical representation of the drainage plan or in the project narrative stating that none exist.

Hydrologic Unit Code

Hydrologic unit codes are used to identify specific watersheds. This information is often used by local governmental entities to identify an individual watershed or watersheds and to analyze and compare various activities between watersheds. Local watershed groups also use this information to implement watershed studies and apply for funding to implement watershed plans.

Hydrologic unit codes are generally expressed in terms of 6-, 8-, 11-, or 14-digit codes. A 14-digit code represents the smallest watershed delineation and is probably the most often requested by local organizations and governmental entities.

Grading Plan

A grading plan is an integral part of any construction project.

Graphically, a grading plan should identify and delineate the construction limits for all earthmoving activities associated with a construction project. The extent of disturbance has a profound impact on what storm water quality measures may be necessary to adequately control erosion and the resulting sedimentation.

Grading plans should also depict the existing and proposed topography of the site. Typically this is done by delineating continuous contour lines or identifying spot elevations on the grading plan. In the case of spot elevations, it is important to have a sufficient number of locations to be able to visualize the site topography. This information is critical to the project planner and grading contractor because it allows them to calculate the areas and quantities of soil cut and fill that may be associated with the project. Often, it is beneficial to provide the cut and fill quantities in tabular format.

Grading plans should identify the potential location of soil stockpile areas, borrow areas, and soil disposal areas. Soil stockpile and borrow site locations can alter the direction of storm water flow during construction activities and can have a significant impact on the selection, location and adequacy of the storm water quality measures.

Often, borrow and disposal areas may occur outside the property boundaries of the project site. In these instances, it is important that project site owners realize all land-disturbing activities associated with their project must comply with Indiana's storm water rule for runoff associated with construction activity. The rule is found in the Indiana Administrative Code under Title 327, Article 15, Chapter

5 (327 IAC 15-5). Unless these off-site borrow and disposal areas are commercially operated facilities permitted under other state regulations, they may need to be identified and included as part of the project site owner's plan submittal or as a separate project.

If a construction project does not have any planned soil stockpiles, borrow areas, or disposal areas associated with it, this should be stated as a note on the grading plan or in the narrative of the construction plans.

Storm Water Pollution Prevention Plans

A storm water pollution prevention plan is a working document that identifies potential pollutants associated with a project and serves as a blueprint for the selection, installation, and maintenance of construction and post-construction storm water quality measures designed to control or reduce the impact of the pollutants. It also specifies how storm water will be managed at the project site. A storm water pollution prevention plan should be part of the general construction plan and not a stand-alone document because of its interrelationship with other plan components. It is also important to understand that changes to one or more facets of the construction plans can drastically affect provisions that have been identified in the storm water pollution prevention plan.

The purpose of a storm water pollution prevention plan is twofold. First, it serves as the principle site reference identifying storm water quality measures that need to be implemented to reduce erosion and minimize the discharge of sediment and other pollutants associated with the project. The second purpose of a storm water pollution prevention plan is to address the reduction of pollutants associated with a project's post-construction land use. In order to choose the appropriate storm water quality treatment measures to meet these objectives, the plan designer must have an understanding of the project site, the intended land use, and the associated pollutant sources.

Development and implementation of a storm water pollution prevention plan should be done by individuals who have an understanding of storm water issues and erosion and sediment control because proper development and implementation is critical if pollutants are to be adequately reduced or controlled. Development of a storm water pollution prevention plan must address planning of the project, the assignment of responsibilities and resources, performance expectations, and standards for monitoring performance compliance.

Storm water pollution prevention plans contain an array or variety of storm water quality measures that are designed to protect water quality. In general, a storm water pollution prevention plan can be divided into two different components: (1) an erosion and sediment control plan and (2) a post-construction pollution prevention plan. Each of these plan components should identify and clearly convey when, where, and how each storm water quality measure will be installed and maintained. At a minimum each component should contain the following items.

- Appropriate storm water quality measures.
- Location of each measure on the project site.
- Design standards and specifications for each measure.
- Installation criteria for each measure.
- Construction schedule describing the implementation/installation of the storm water quality measures relative to land-disturbing activities.
- Maintenance of all storm water quality measures.

Many of the storm water quality measures identified in a storm water pollution prevention plan will be implemented throughout the life of the project. It is important to recognize that some post-construction measures can be modified to control sedimentation during a project's construction phase and then modified to its original design to treat post-construction storm water runoff and pollutants after construction has been completed.

Associated Local, State, and Federal Water Quality Permits

On many projects, numerous local, state and federal water quality permits are required. Often, it is beneficial to include a listing of associated water quality permits within the storm water pollution prevention plan, in the project narrative, or on appropriate plan sheets. This facilitates coordination of the permitting processes and can prevent lengthy delays of a project.

The types of water quality permits associated with construction projects include but are not limited to:

- Construction in a Floodway Permit from the Indiana Department of Natural Resources' Division of Water.
- National Pollutant Discharge Elimination System Permit from the Indiana Department of Environmental Management's Office of Water Quality.
- Section 401 Water Quality Certification Permit from the Indiana Department of Environmental Management's Office of Water Quality.
- Section 404 Water Quality Permit from the United States Army Corps of Engineers.

Later chapters of this manual will provide more in-depth discussion and instruction on the development and implementation of storm water pollution prevention plans and the selection of storm water quality measures available to reduce or control pollutants associated with a project's construction and post-construction activities.

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Above photo source:
Natural Resources Conservation Service, Iowa

Planning Principles & Design Considerations

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PLANNING PRINCIPLES & DESIGN CONSIDERATIONS

Project planning, design, and layout can begin once all site information and data has been collected and analyzed. The first step in planning, design, and layout is to develop a set of construction plans including a comprehensive site plan.

A site plan is a graphical depiction showing the layout of a project. Site plans typically include the location, design, and specifications for roads, streets and parking areas; storm water management systems, wastewater management systems, utilities, and other infrastructure; structures; landscaping and common areas; and other facilities associated with the project.

Development of the site plan should take into consideration all of the information collected during the site assessment and data collection process. When making planning, design, and layout decisions, it is extremely important to take advantage of the strengths and overcome the limitations of project site features identified in the assessment process. Adapting a plan design to existing site conditions and the natural features of the landscape can greatly reduce the project's environmental impacts.

Storm water management, including erosion and sediment control and post-construction pollution prevention measures, needs to be an integral part of the site planning process and not just an afterthought. Again, it is extremely important to take into consideration details for land clearing, grading, and cut and fill operations that will be used during the construction process when developing the site plan. Therefore, the best approach to developing a set of comprehensive construction plans is to prepare the site plan and storm water pollution prevention plan simultaneously.

This section contains several basic planning principles and design considerations that should be reviewed and incorporated into the site planning process whenever possible. Using these principles and design considerations will help reduce environmental impacts and minimize project construction costs.

The following illustrations show a comparison of conventional design versus a design that incorporates planning principles and consideration for the natural site features.

Conventional Design

Source: Georgia Stormwater Management Manual, 2001

Improved Site Design

Source: Georgia Stormwater Management Manual, 2001

One of the first activities that should be performed at a project site is a site assessment of resource issues. This process includes inventory and data collection of the resources that are associated with the project site. This process is described in more detail in Chapter 2 of this manual.

This section provides an in depth discussion of key natural features that may be encountered at a project site. The intent of this section to provide an understanding of each of these resource features and issues with an emphasis on protection. Incorporating these natural features into the design and layout of the project site can minimize the overall impact of the project. Benefits include but are not limited to a reduction of impervious surfaces, decreased generation of pollutants, and treatment of storm water runoff.

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Preservation of Natural Vegetation

The ***preservation of natural vegetation*** *during construction provides natural buffer zones, protects soils from water and wind erosion, removes sediments and other pollutants from storm water runoff, and is aesthetically pleasing. This technique can be applied to all types of sites.*

Key Benefits

- Vegetation absorbs the energy of falling rain.
- Dense root structures hold soils in place and increase the soil's absorptive capacity.
- Plant roots hold soil particles in place and preserve and promote development of soil structure, resulting in increased soil permeability which increases the soil's ability to absorb storm water runoff.
- Vegetation also:
  - Slows the velocity of runoff and acts as a filter to trap sediment.
  - Serves as a buffer zone against noise.
  - Enhances aesthetics of the area.
  - Provides areas where wildlife can remain undisturbed.
  - Provides a source of shade during summer months.
  - May add to the value of residential and commercial properties.
  - Usually requires less maintenance than planting new vegetation.

Planning Consideration

- Extremely well-suited for use in areas prone to high rates of soil erosion where other soil erosion control measures would be difficult to establish, install, or maintain.
- Use in areas where it is desirable to reduce storm water runoff sheet flow velocities.
- Can be used to protect unique or endangered plant species.

Discussion

Soil erosion is a leading cause of water quality problems in Indiana. It impacts water quality by degrading the habitat of aquatic organisms and fish, promotes the growth of nuisance weeds and algae, and decreases its recreational value. During construction, if disturbed land is left unprotected its erosion potential increases, storm water runoff volumes and sediment loadings increase, and the potential for surface water degradation increases.

The preservation of vegetation should be planned before any site disturbance begins. Planners should note the locations where vegetation should be preserved and consider this when determining the location of roads, buildings, or other structures. Highly visible barricades and signs should be erected to protect vegetation boundaries selected for preservation. Preventing damage is less costly than correcting it.

Planning should include the maintenance requirements of the existing vegetation. Based on soil types and climate, different species will require different maintenance activities such as mowing, fertilization, irrigation, pruning, and weed/pest control. These activities should be performed regularly during construction.

Riparian Buffer Zones

Source: Natural Resources Conservation Service, Iowa

***Riparian buffer zones** are natural vegetative zones along creeks, streams, channels, or other waterbodies. They typically consist of tree, shrub, and grass plantings.*

Key Benefits

- Riparian buffer zones help:
  - Maintain the integrity of stream channels and shorelines.
  - Remove pollutants such as suspended solids, phosphorous, nitrates, trace metals, pesticides, and hydrocarbons from storm water runoff.
  - Remove nutrients and other pollutants from subsurface flow through filtering and plant uptake.

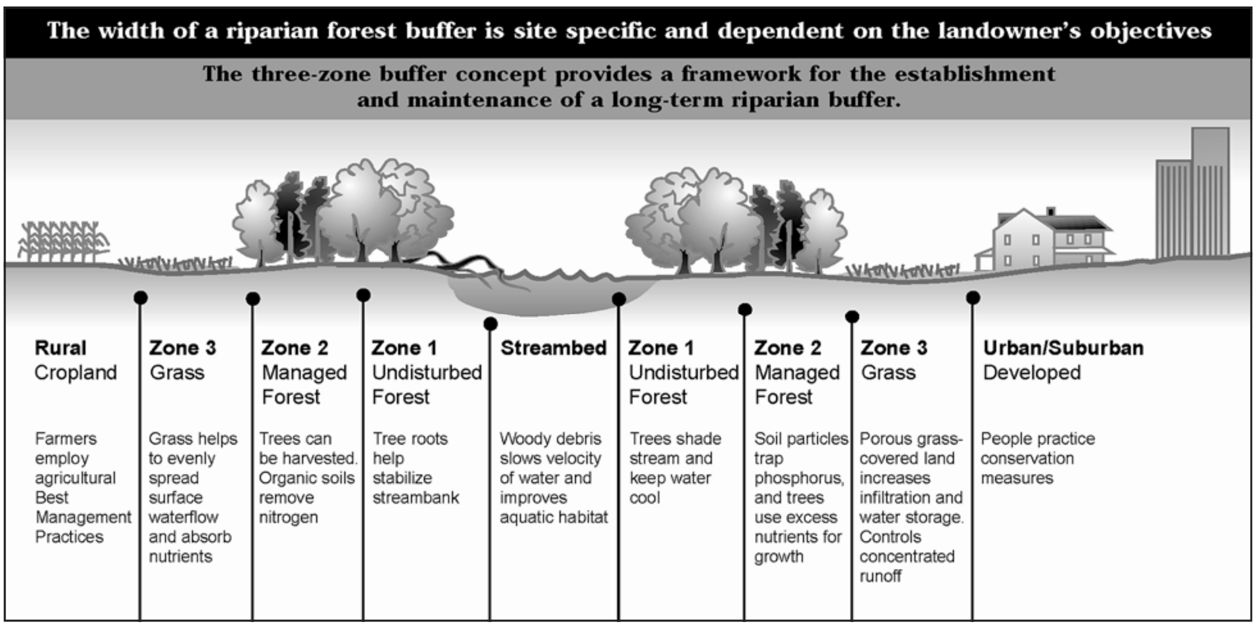
- Riparian buffer zones supply food, cover, and shade (thermal protection) to fish and other wildlife.
- Riparian buffer zones provide:
  - Green space and wildlife corridors.
  - Recreational areas such as parks and walking trails.

Planning Consideration

- Use along fields, housing developments, industrial and commercial sites, etc. where it is desirable to protect streambanks and drainage channels and to decrease nonpoint source pollution of waterbodies.
- Can be used along streams and drainage channels where it is desirable to preserve native vegetation and buffers both during and after active land-disturbing activities.
- Well suited for setting aside areas for wildlife food and habitat.

Discussion

Riparian buffer zones are typically found connecting a stream system and a people-based system such as agriculture, housing, or industry. From the water's edge and continuing up slope, the area can be viewed in zones. The "three-zone buffer concept" is the most common type of riparian buffer zone system. Zone 1 is a mix of undisturbed, native trees and provides bank stabilization as well as shading and protection for the stream. This zone may also include wetlands and any critical habitats. Zone 2 is a transition zone consisting of native trees, shrubs, and grasses. This area can be used for various purposes such as timber harvesting, wildlife habitat, and outdoor recreation. Zone 3 consists of a dense mixture of grasses and forbs (broad-leaved herbaceous plants and wildflowers). This zone acts as a further setback between the waterbody and impervious surface areas. It provides more permeable surface area for infiltration of storm water runoff into the soil. The vegetation in this zone also helps convert concentrated storm water runoff into sheet flow, maximizing surface area for infiltration of runoff.



Source: Maryland Cooperative Extension, Fact Sheet FS724, 1998

Riparian buffer zones are very important in minimizing nonpoint source pollution of waterways from adjacent land, protecting aquatic environments, enhancing wildlife habitat, and increasing biodiversity. The roots of riparian vegetation also help stabilize streambanks and shorelines and therefore are important in minimizing streambank and shoreline erosion potential.

During construction of a project, riparian buffers that are to be preserved should be protected from excessive sediment loads by installing appropriate erosion and sediment control measures.

In general riparian buffer zones should be kept in their natural state. However, some upkeep such as planting to minimize concentrated flow, removal of exotic species, and removal of damaged or diseased trees may be necessary.

Installation of riparian buffer zones on agricultural lands should take into consideration the location of crop lands, grazing lands, livestock enclosures, and pasture lands. Developments along stream channels and drainageways in urban areas should utilize riparian buffers whenever feasible to protect the stream from nonpoint source pollution and provide for community recreational use. Urban riparian buffers should have easements allowing for protection and maintenance of the vegetation. Urban riparian buffer zones can also be an effective selling point when landowners want the benefits a buffer can provide or where a high level of benefit can be derived at an acceptable cost to the landowner and the public.

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Wetlands

Wetlands *are areas that are saturated by surface water or ground water for extensive periods of time and have the ability to support water-loving plants as a result of hydric soil conditions.*

Key Benefits

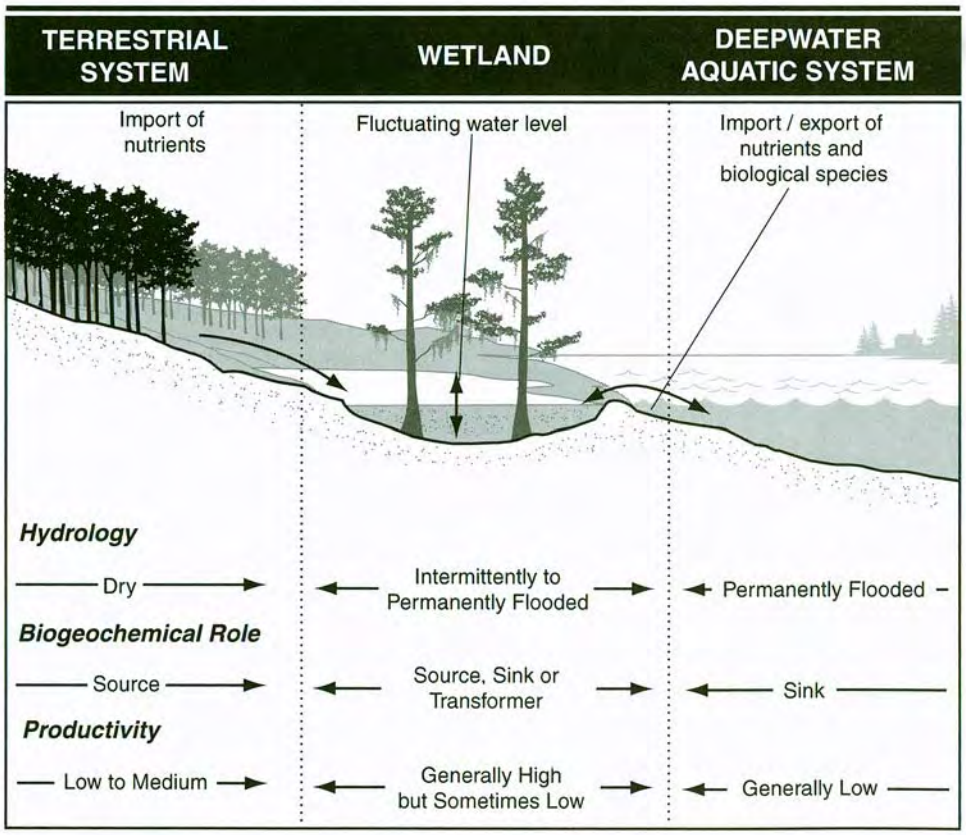
- Wetlands help remove excess nutrients and trap sediments and other pollutants contained in storm water runoff via infiltration, absorption, ion exchange, precipitation, and biodegradation thereby preventing pollutants from reaching rivers, lakes, and other waterbodies.
- Wetlands help slow and absorb flood waters.
- Wetlands provide habitat for thousands of species of aquatic and terrestrial plants and animals.

Planning Consideration

- Well suited for use in areas designated to be set aside for the preservation of plant and animal life and biodiversity.
- Can be used in areas where it is desirable to capture storm water runoff and allow ground water recharge.
- May be used to reduce flooding potential.
- Consider limited capacity for handling increased flows and pollutant loadings.
- Natural wetlands should not be used as a primary treatment measure to capture pollutants; consider pretreatment.

Discussion

Wetlands serve important water quality improvement functions within the landscape. They are a major link between land and water. One of the functions performed by wetlands is the filtering of nutrients such as phosphorous and nitrogen. Due to their unique position in the landscape, wetlands serve as natural receptacles for storm water runoff and can absorb enough water to help control flooding. Wetlands also have the ability to soak up storm water runoff during storms and then slowly release the water over extended periods of time.



Source: Adapted from *Wetlands*, 3rd Ed., 2000 by Mitsch, William J. and Gosselink

The above functions should be taken into consideration when developing storm water management strategies for lands undergoing land use changes. However, when considering diverting flows to a wetland (either from storm water sources or non-storm water sources), it is important to consider that they do have a limited capacity for handling increased flows or additional pollutant loadings. In urban areas wetlands are dramatically altered by uncontrolled run-off, either through natural drainage to those systems or direct discharge.

Flood Plains

***Flood plains** are areas consisting of drainage channels and adjoining dry land areas that are susceptible to being inundated by water from any natural source.*

Key Benefits

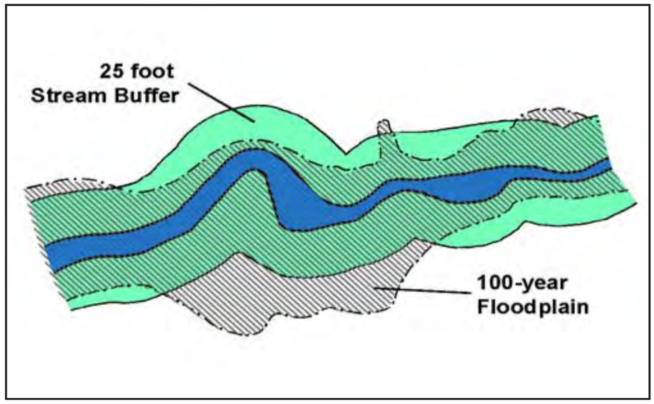
- Flood plains provide a natural right-of-way and temporary storage for large flood events.
- Flood plains protect people and structures from flood water harm and damage.
- Flood plains help preserve riparian ecosystems and habitats.
- Flood plains may be used in conjunction with riparian buffer zones to create linear greenways.

Planning Consideration

- Consider using in areas where there is a need to protect humans or structures from flood water harm or damage.
- Use where it is desirable to preserve aquatic and terrestrial habitats and biodiversity.

Discussion

A flood plain consists of a stream or drainage channel and low-lying areas bordering the stream or channel. When the stream or channel reaches its capacity after a heavy rain or a significant snow melt event, the channel overflows into the flood plain. This makes flood plains very beneficial because of their storage and conveyance capacity and ability to reduce the volume and velocity of flood waters. By reducing flood water volumes and velocities, flood plains have the added benefit of allowing for the settlement and removal of sediments and other suspended solids commonly found in storm water runoff. Flood plains are also very important to the survival of aquatic and terrestrial life and preservation of biodiversity.



Source: Georgia Stormwater Management Manual, 2001

Streams and other watercourses should be allowed to naturally flow through their own corridors. When development encroaches on a flood plain, its ability to convey storm water is greatly reduced and the potential for human or structural harm is elevated. Most communities regulate the use of flood plains in order to avoid these risks. Ideally the 100-year flood plain should be avoided for clearing and building. The best case scenario is one in which the entire 100-year flood plain is left in a natural state. Many times this area coincides with the riparian stream buffer. Both practices preserve the stream corridor in its natural state and protect existing wildlife habitat and vegetation. The boundaries of the 100-year flood plain may lie within or outside the riparian stream buffer zone.

Maps of 100-year flood plains are generally available through local planning, zoning, or building departments. It is important to note that developers and building designers must comply with Federal Emergency Management Agency requirements.

Flood plains are often inconspicuous on smaller conveyance systems, but they serve the same function as flood plains on larger creeks, streams, and rivers. To maintain the integrity and function of flood plains, construction activities and the placement of fill materials in the flood plain should be avoided. Wherever possible, construction activities and development in flood plains should be avoided. In may instances, flood plains can be integrated into the project design to create a level of aesthetic value and /or used as a natural or recreational area.

The Indiana Department of Natural Resources' Division of Water regulates activities conducted within the floodway of Indiana creeks, streams, rivers, and other conveyance systems. Site designers should ensure that activities associated with the project do not impact flood plains and that appropriate permits are obtained for flood plain areas that will be impacted by project operations before the actual activity commences.

Steep Slopes

***Steep slopes** consist of areas where the slope gradient is typically 15 percent or greater. These areas can occur on hillsides, ridges, or along the sides of ravines.*

Planning Consideration

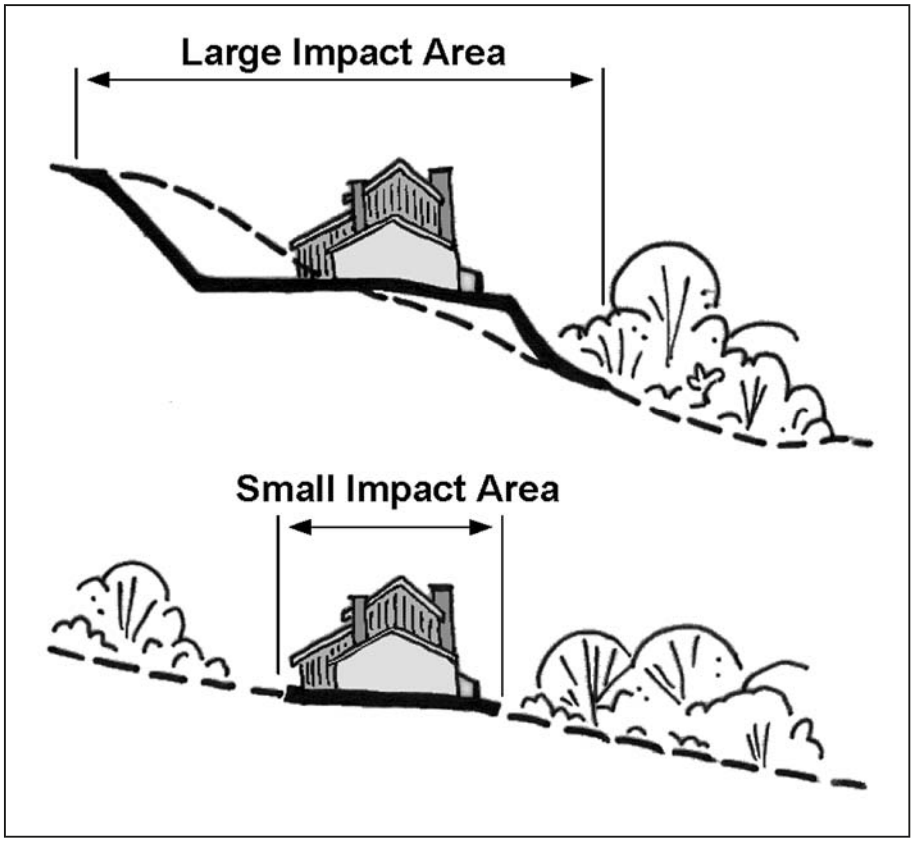
- Avoid development on steep hill, ridge, and ravine slopes, especially those with side slopes of 15 percent or greater.
- Preserve existing vegetation to minimize erosion potential and generation of sediment. (Preservation of existing vegetation eliminates the difficulty of trying to re-establish vegetation in these areas.)
- Build on flatter areas to reduce soil cut-and-fill volumes and the cost of grading operations.

Discussion

Developing on steep slopes causes increased soil erosion and storm water runoff during and after construction. U.S. Department of Agriculture Natural Resources Conservation Service studies have shown that soil erosion is greatly increased on slopes that have a grade of 15 percent or more. Developing on steep slopes also results in excessive sediment loading of storm water runoff. Therefore, developing on slopes with a grade of 15 percent or greater should be avoided whenever feasible in order to minimize erosion, soil loss, degradation of surface water, and excessive storm water runoff. Furthermore, slopes with a grade of 25 percent or more should be avoided altogether.

STEEP SLOPES

More land is disturbed when developing steep slopes versus development of flat ground. Ideally, steep slopes should be left in their natural, undisturbed state to preserve the natural topography and character of the site, the natural soil and associated soil characteristics, and existing vegetation. Leaving areas undisturbed will minimize erosion potential, protect water quality, and minimize grading costs.



Source: Georgia Stormwater Management Manual, 2001

Karst

Source: Richard Fields, Indiana Department of Natural Resources

***Karst** is a landscape feature characterized by sinkholes, ravines, crevices, and underground streams and caves formed in soluble calcium carbonate or dolomite (calcium magnesium carbonate) limestone bedrock. These features are formed when the bedrock is dissolved by water.*

Planning Consideration

- Measures should be used to reduce concentration of runoff.
- Storm water conveyance structures should be used to allow increased infiltration and reduce pollutants generated.
- Investigate areas underlain by carbonate rock to identify sink holes.
- Where feasible, direct storm water runoff 1000 feet or more away from the edge of existing sinkholes and if possible, discharge it to an area that is not underlain by limestone bedrock.

Discussion

From a storm water management perspective it is very important to identify karst sinkholes, fractures, and cavities due to their potential to pose environmental threats and/or construction hazards.

In karst areas, surface water flows very quickly into caves and sinkholes resulting in very little time for storm water to infiltrate into the soil. Storm water runoff often picks up contaminants such as human and animal waste, pesticides, fertilizers, petroleum products, and other pollutants as it flows across the earth's surface. When this contaminated runoff enters karst features it can travel great distances underground and may result in the contamination of wells, springs, and aquifers. Spills of pollutants such as chemicals and hazardous materials are of special concern in these areas. In addition, impacts on aquatic cave-dwelling species can result in adverse effects of biologic communities. For example, endangered species such as the blind cave fish are especially prone to the adverse effects of contaminated storm water runoff.

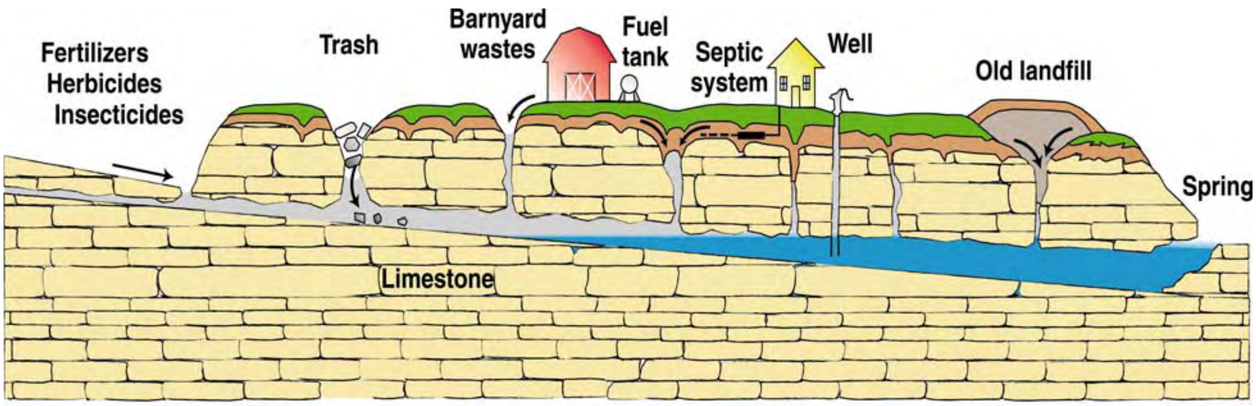
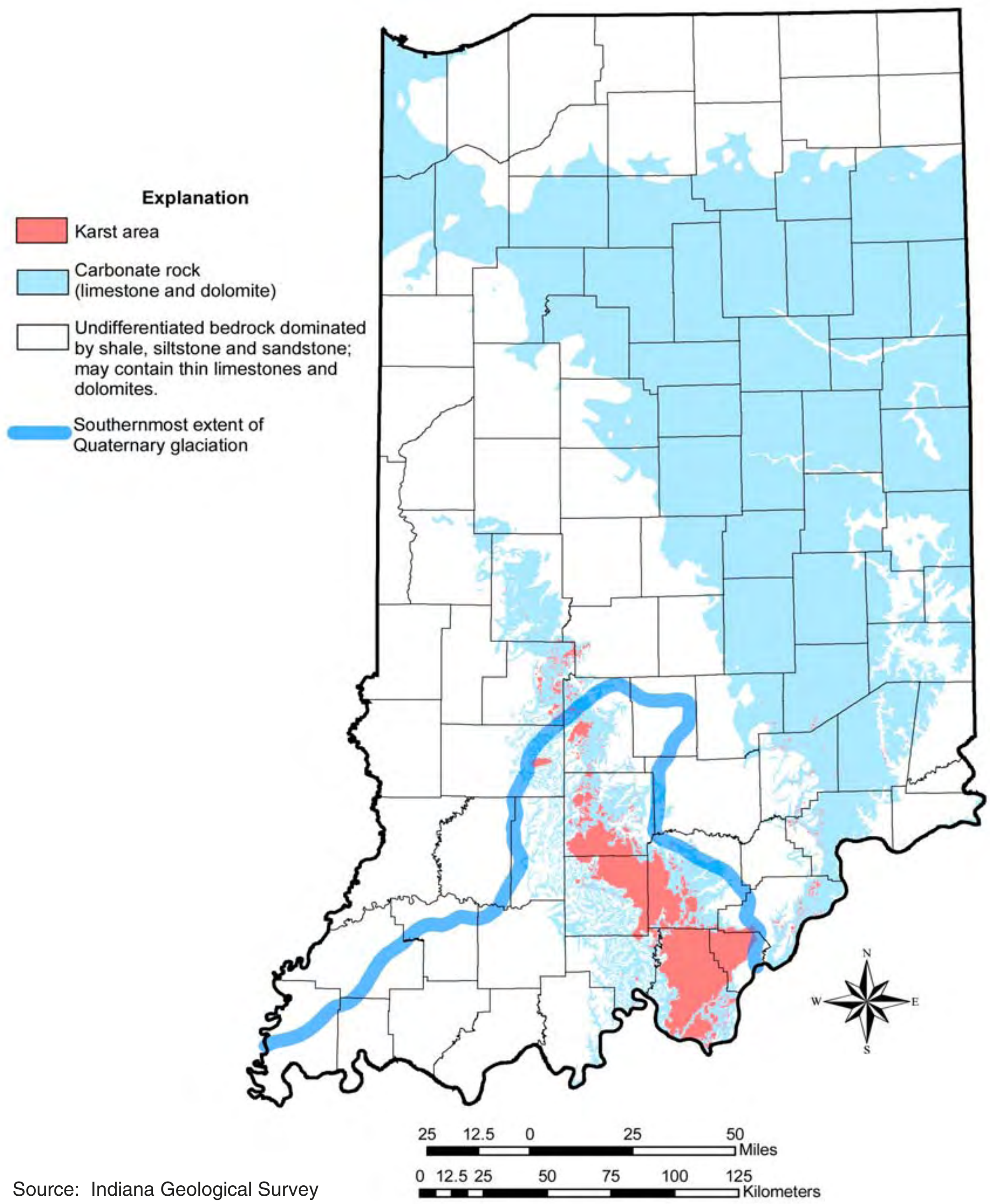


Diagram concept by Indiana Geological Survey, R.L. Powell; drafted by R.S. Taylor

Percolation of surface water into the soil and underlying limestone bedrock of karst areas often results in sinkholes and underground caves. Construction activities often accelerate sinkhole formation due to the disturbance of existing soil and bedrock conditions and the alteration of existing hydrology and drainage patterns. To help reduce the impact, emphasis should be placed on reducing runoff through aggressive mulching and seeding measures. In addition, the increase in impervious surface cover and increased structural loads on the soil frequently result in ground failure. For these reasons detention/retention ponds should be designed and constructed with a liner and discharges from storm water management facilities and impervious surfaces should be routed to stable areas. The use of buffers are encouraged adjacent to karst features, especially in areas where

large amounts of impervious surface must be added. One way to accomplish this is to maintain large vegetative strips on slopes to help filter and slow runoff. In addition, alternative measures can be substituted for impervious surfaces to allow more absorption of flow and less runoff. These measures include but are not limited to porous pavers, pervious concrete, and porous asphalt. The use of infiltration measures should be carefully evaluated before their use. Where feasible, storm water flows should be directed away from limestone bedrock.

For the protection of ground water quality, storm water conveyance measures that are to be used in karst areas should be designed to spread or disperse storm water runoff over the largest area practicable. Dispersion of storm water runoff helps eliminate concentrated flows and the pooling or ponding of runoff. Grass waterways are another effective storm water management measure that can be used in karst areas.



Source: Indiana Geological Survey

Additional Resources

Internet:
Indiana Geological Survey
http://igs.indiana.edu/index.cfm

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LAND/SITE UTILIZATION

After gaining an understanding of the natural resources occurring on the project site it is time to begin to understand how the project can be designed with each of these features in mind.

This section provides an in-depth discussion of several project management activities that should be considered early in the design process. These activities include fitting the design and layout of the project to the natural landscape, restricting land disturbance in unique resource areas, planning land disturbance in an orderly fashion to reduce the amount of bare earth exposed at a given time, and utilizing existing buffers, riparian corridors, and vegetated areas as either amenities or part of the storm water management system. There is also a discussion of the importance of soil properties and how soils are directly related to site planning, design, and the selection of storm water measures.

Incorporating these land use decisions into the design and layout of the project site can minimize the overall impact of the project. Benefits include but are not limited to site aesthetics, reduction of impervious surfaces, decreased generation of pollutants, and treatment of storm water runoff.

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Soil Properties

Source: Natural Resources Conservation Service

***Soil properties**, limitations, and hazards play a very important part in the planning, design, and layout of a project. This planning principle affects nearly every aspect of a project.*

Planning Consideration

- Leave highly erodible or unstable soils in their natural condition to prevent erosion, sedimentation, and water quality degradation problems.
- Leave highly erodible or porous soils as undisturbed conservation areas.
- Use permeable soils as nonstructural storm water infiltration zones.

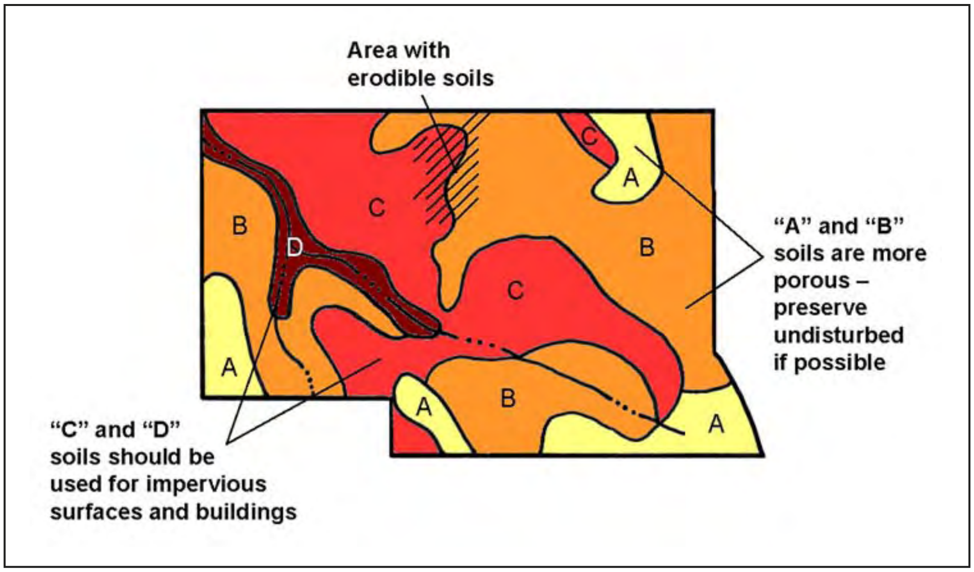
Discussion

Soils generally have the greatest impact on project planning, design, and layout. Their inherent properties, limitations, and hazards can literally dictate the layout of building lots/pads, roads and streets, storm sewers, on-site sewage disposal facilities (where applicable), and other project infrastructure. Soils also play a significant role in the selection and installation of construction and post-construction storm water management measures.

Planning, Design, and Layout

Soil characteristics such as depth to bedrock, depth to the seasonal water table, permeability, shrink-swell potential, texture, erodibility, etc. need to be evaluated and factored into the design and layout of a project. Soils data must also be taken into account when evaluating, selecting, locating, and designing construction and post-construction storm water management measures for the management and treatment of storm water runoff.

General soils maps, found in Natural Resources Conservation Service county soil surveys, are often an excellent place to start when incorporating soils information into the site plan and storm water management plan. General soils maps provide groupings of soils with similar properties. Depending on the size of the project, general soils maps can be used to guide the placement of buildings and impervious surfaces and select the most suitable areas of the project site for common areas, greenways, buffer zones, and natural preservation.



Source: Georgia Stormwater Management Manual, 2001

Local soil resource maps and interpretive tables, also found in Natural Resources Conservation Service county soil surveys, can be useful in the planning, design, and layout of a project site. The soil resource maps can be used to identify and delineate specific soil types on the site plan and the tables can be used to group soils with similar characteristics, properties, limitations, and hazards. For example, these maps and tables can be used to identify highly erodible soils and unstable soils that should be maintained in their natural state to minimize erosion potential and sediment impacts and avoid potential structural damage to buildings.

Construction

Soils can have a significant impact on the location and stability of buildings and roads and streets. Soils with a seasonal high water table can affect the stability of roads and streets and result in frost action problems in colder climates. A high water table can result in flooded crawl spaces or basements of buildings.

Development of the site plan must take soil properties, limitations, and hazards into account when determining the location of buildings and roads and streets. Areas of highly erodible or unstable soils should be avoided to the greatest extent practicable to avoid erosion, sedimentation and potential structural problems. If structures must be located on highly erodible soils, the storm water pollution prevention plan should identify storm water measures that can be used to minimize erosion on these areas.

Permeable soils suitable for infiltration of storm water runoff should be left in their natural state and to the greatest extent practicable, preserved for use as natural space such as common areas and greenways. On projects requiring the construction of buildings and roads/streets, locate the structures on soils with more restrictive permeabilities or very rapid permeabilities and reserve the permeable soils for storm water infiltration and treatment.

Post-Construction

Soils play a major role in the selection and implementation of post-construction storm water quality measures. Soil properties can literally dictate whether or not to use filtration and/or infiltration measures. For example, the use of filtration and infiltration practices may be severely restricted or impractical in soils with a seasonal high water table unless there is some way to artificially lower the water table. Infiltration measures will be ineffective in soils that have a high clay content or soils that have an extremely high gravel content.

Porous sandy and gravelly soils allow storm water runoff to infiltrate and recharge ground water supplies. Dispersion of storm water runoff over these highly permeable soils helps reduce the amount of runoff and reduces peak discharges. Areas of permeable soils should be considered as a storm water management option, provided that the soils are not easily erodible or unstable.

Permeable soils, such as sands and sandy loams (hydrologic soil group A and B), provide infiltration into the subsoil at a rate that allows for the removal of some storm water pollutants. Conversely, very rapidly permeable soils like coarse sands and gravel provide little opportunity for the removal of storm water pollutants.

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Reduce Limits of Clearing & Grading

***Reducing the limits of clearing and grading** is a planning principle that can be used to preserve existing vegetation, natural drainage patterns, and the aesthetics of a project site. In addition, this principle helps minimize the clearing and grading costs associated with a construction project.*

Planning Consideration

- Natural conservation areas and other site features can be protected using these techniques.
- More undisturbed natural area on a site is preserved.
- Set up limits of disturbance for development activities.
- Limit the site footprint to reduce the clearing and disturbance of a site.

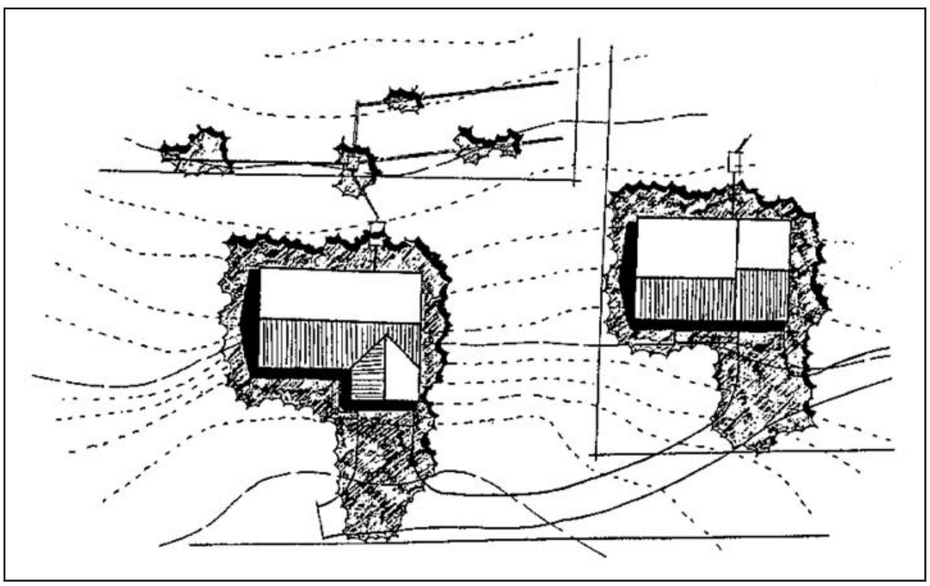
Discussion

Minimizing clearing and grading on a construction site helps to preserve existing vegetation and natural drainage patterns of the site. Preservation of these features often enhances the project's aesthetics and helps minimize the costs associated with clearing and grading of the project. Clearing and grading of areas highly susceptible to erosion generally requires the installation of more sophisticated and costly storm water quality measures to control erosion and sedimentation on the construction site.

To the greatest extent practicable, clearing and grading activities should be confined to the least critical areas on the project site. Long, steep slopes, areas of highly erodible soils, unique natural areas, etc. should be used as open space or natural areas on the project site. Where possible, minimize the number and width of site access roads and locate them in areas that will be used later for streets, utility corridors, and rights-of-way. Locate areas designated for staging of construction equipment, employee parking areas, construction offices/trailers, and construction material and soil stockpile areas in zones designated for future clearing and grading.

There are several methods that can be used to reduce the limits of clearing and grading. These methods are typically referred to as minimal disturbance methods. The most common minimum disturbance methods used include limiting the footprint of land disturbance and development, fitting the site design to existing terrain, and using special procedures and equipment.

The limit of disturbance should reflect reasonable construction techniques and equipment needs together with the physical characteristics of the development site such as soils or slope. Limit of disturbance distances may vary depending on the type of development, the size of the project site, and the specific development features involved.



Source: Delaware Department of Natural Resources and Environmental Control and the Brandywine Conservancy, 1997

Limiting the footprint of construction is another method that can be used to reduce the limits of clearing and grading. This method maps all of the limit of disturbances to find the smallest possible area to be cleared or disturbed. The photograph on the next page illustrates the use of this method to minimize disturbance of existing vegetation.

Source: Georgia Stormwater Management Manual, 2001

The third method used to reduce the limits of clearing and grading is fitting the project site design to the existing terrain. This method and the use of special procedures and equipment is discussed further in other sections of this manual.

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Fit the Design to the Existing Terrain

Source: Georgia Stormwater Management Manual, 2001

***Fitting the design to the existing terrain** allows for the planning, design, and placement of buildings, roads/streets, utilities, and other infrastructure in a manner that compliments the existing topography and minimizes the amount of clearing and grading of the project site.*

Key Benefits

- Aids in preserving the natural hydrology and drainageways of a site.
- Decreases the need for grading and land disturbance.
- Minimizes erosion potential, environmental impacts, and project costs.

Planning Consideration

- Plan and lay out roads and streets to follow natural landforms.
- Position buildings and other impervious surfaces away from steep slopes, drainageways, and flood plains.

Discussion

When developing a project, the site design should be tailored to fit existing site conditions and avoid unnecessary land disturbance. Buildings, roads/streets, utilities, infrastructure, and other features associated with the project should be tailored to fit the existing terrain. Taking this approach lessens the impact to the existing soil and vegetation and preserves the hydrology and natural drainage patterns of the site. Fitting the design of the project to the terrain also reduces the amount of clearing and grading which in turn minimizes erosion, environmental impacts, and project costs.

Buildings and impervious surface areas should be kept away from steep slopes, natural drainageways, and flood plains. They should be located in areas of existing, flat terrain to allow existing drainage systems to remain in place. The major axis of buildings should be kept parallel to the contour of the land.

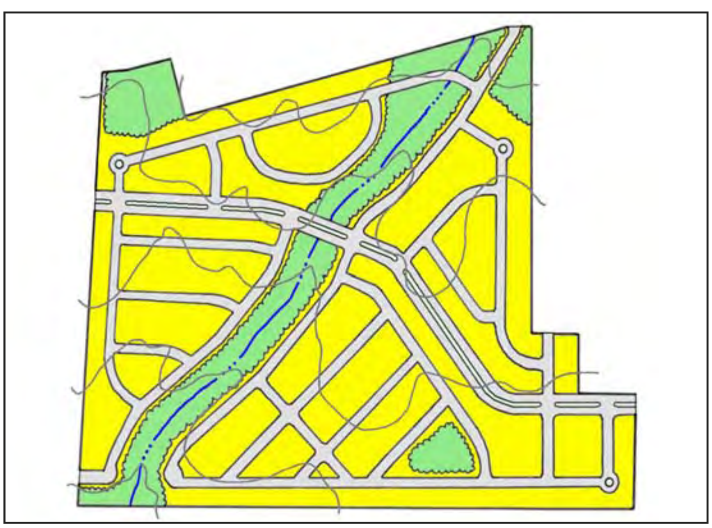
FIT THE DESIGN TO THE EXISTING TERRAIN

Roads and streets should follow the natural landforms and should be designed around natural drainageways and stream buffer zones. For example, in rolling, dissected terrain, collector roads and streets should follow ridgelines and natural valleys/ravines. This greatly reduces the amount of clearing and grading required. Roads and streets branching off of these main collector streets should form short loops or end in cul-de-sacs. This pattern resembles the branched pattern of ridgelines and drainageways in the natural landscape. This pattern also minimizes the removal of vegetation on existing, steep grades and reduces the number of natural stream and drainageway crossings. In places where the terrain is flat, it is easier to lay the roads and streets out in a grid like pattern because drainage patterns will be less complicated.

Development on Steep Terrain

Source: Georgia Stormwater Management Manual, 2001

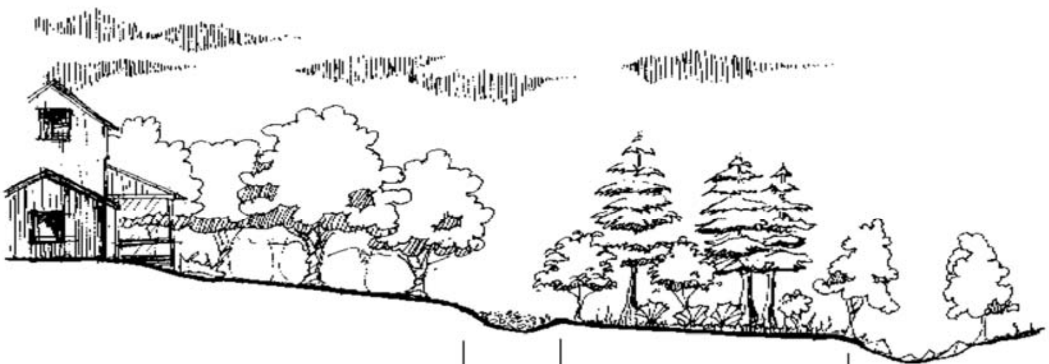
Development on Flat Terrain



Source: Georgia Stormwater Management Manual, 2001

Utilize Undisturbed Areas & Natural Buffers

Preserving undisturbed areas and using natural buffers *is a planning and site design principle that can be effectively used to minimize clearing and grading, filter and infiltrate storm water runoff, reduce environmental impacts, and minimize the cost of development. The theory behind using undisturbed areas and natural buffer zones is to intercept storm water runoff before it becomes concentrated and disperse it evenly over the natural area or buffer zone.*



Source: Adapted from North Carolina Department of Environment and Natural Resources, 1998

Key Benefits

- Makes use of vegetated areas to filter and infiltrate storm water runoff.
- Directing runoff towards pervious vegetated areas increases overland flow time and reduces peak flows.
- Natural depressions provide for inexpensive storage and detention of storm water runoff.

Planning Consideration

- Minimize the amount of impervious surface area and use storm water management measures to convert concentrated flows from the impervious areas into sheet flow that is discharged into pervious, vegetated areas.
- Use storm water management measures to convert concentrated flows into sheet flows and direct the runoff towards vegetated buffer zones and undisturbed areas.
- Use natural depressions for storage of storm water runoff.

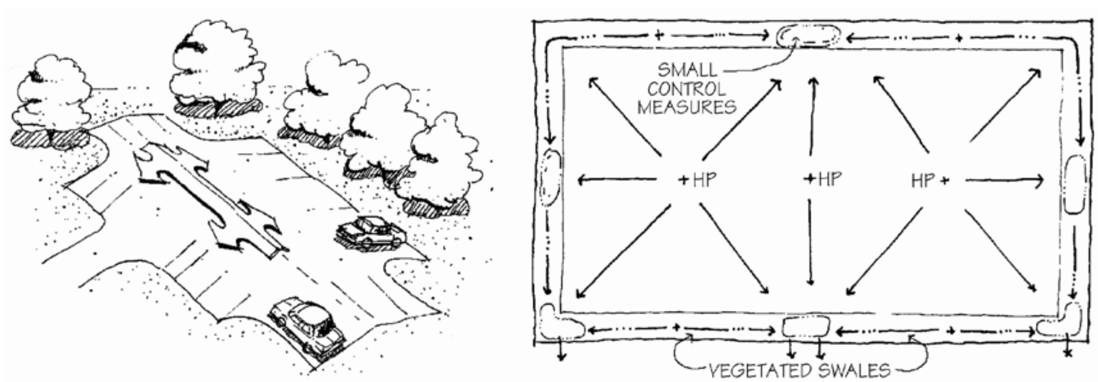
Discussion

Directing storm water runoff from impervious surface areas to undisturbed natural areas, vegetated areas, riparian buffer zones, and other undisturbed natural areas slows storm water runoff and allows the runoff to infiltrate into the soil. These vegetated areas and buffer zones also facilitate the removal of storm water pollutants via infiltration, absorption, ion exchange, precipitation, and biodegradation thereby preventing pollutants from reaching rivers, lakes, and other waterbodies.

Natural depressions can be used to store storm water runoff temporarily and allow it to infiltrate into the underlying soil (especially in areas of porous soils). In this way, the runoff is “disconnected” from hydraulically efficient structural conveyances such as a curb and gutter or storm drain systems.

Methods for disconnecting impervious areas include using roof designs that drain to vegetated areas, directing storm water runoff from impervious surfaces to vegetated areas, diverging the direction of storm water flow from impervious surfaces (e.g., parking lots), and shaping landscaped areas to shed storm water sheet flows to pervious areas.

Paved Surfaces Designed to Disperse Flow to Vegetated Areas



Source: North Carolina Department of Environment and Natural Resources, 1998

PLANNING PRINCIPLES

Once the designer is knowledgeable of the project site and begins to plan the layout, design, and infrastructure there are still many decisions to be made. There are numerous storm water quality measures that can be selected to manage storm water quantity, treat storm water runoff, and reduce the discharge of pollutants that will be associated with the final land use. Before the final selection of storm water quality measures, there are other planning and design opportunities that should be taken into account by the designer.

This section provides an in-depth discussion of several planning or design principles that should be considered early in the project. The principles described in this section are a variation of typical project design. The principles include but are not limited to creative development design, roadway design, building and parking lot footprints, setbacks and frontages, and storm water conveyance system alternatives. Communities across Indiana have strict guidelines or ordinances that apply to the design of subdivisions, commercial projects, and other development. Most of the principles described in this section have not necessarily been adopted or incorporated into local ordinances and may require a special approval or a variance from local plan authorities.

Incorporating these planning principles into the design and layout of the project site can minimize the overall impact of the project. Benefits include but are not limited to site aesthetics, reduction of impervious surfaces, decreased generation of pollutants, and treatment of storm water runoff.

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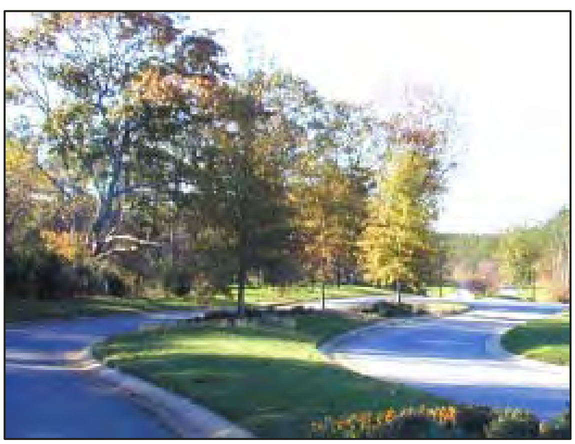
Creative Development Design

Creative development design *is a planning principle that can be used to reduce the amount of impervious cover on a project site. The theory behind this principle is to reduce storm water runoff volumes and velocities by reducing the percentage of pervious cover, allowing for increased infiltration of storm water into the soil.*

Examples of Reducing Impervious Cover

Cul-de-Sac with Landscaped Island

Narrower Residential Street



Landscape Median in Roadway

"Green" Parking Lot with Landscaped Islands

Source: Georgia Stormwater Management Manual, 2001

Key Benefits

- Reduces storm water runoff volumes and velocities.
- Reduces amount of pollutants generated.
- Minimizes environmental impacts.
- Minimizes disturbance to wildlife habitat.
- Preserves aesthetics of project site which can increase salability of lots.

Planning Consideration

- Minimize roadway lengths and widths.
- Minimize building footprints.
- Minimize parking footprints.
- Reduce setbacks and frontages.
- Reduce the radius of cul-de-sacs.
- Use fewer or alternative cul-de-sacs.

Discussion

A primary focus of urban and suburban storm water management planning is to minimize the frequency and severity of flooding. This is generally done by reducing peak discharges from new development. Reducing peak discharges requires generating a site design that minimizes the use of pavement and impervious surfaces, incorporates infiltration measures to restore predevelopment runoff volumes, and uses vegetated drainage swales designed to match predevelopment storm water runoff velocities.

One of the most essential parts of better site design is related to the amount of impervious cover. Impervious cover includes sidewalks, roads, rooftops, parking lots, and basically any surface that does not allow water to infiltrate into the soil. The more impervious cover in an area, the greater the amount of storm water generated. Large amounts of storm water increase pollutant loadings. Conversely, a site designer can reduce the amount of storm water that is generated by reducing the amount of impervious cover.

"Cluster development" is one design concept that can be used to reduce impervious surface cover. This design concept minimizes the amount of land disturbance, concentrates utility lines and connections in one area or corridor, and provides more open, natural space. "Cluster development" also reduces environmental impacts by decreasing the amount of soil exposed to erosive forces and decreasing the amount of impervious surface area which results in less storm water runoff. Another advantage of "cluster development" is that it generally reduces overall development costs by reducing the amount and size of clearing and grading operations, paving materials needed for roads and streets, and infrastructure for storm water conveyance/control and treatment.

The principle behind "cluster development" is to concentrate development within one section of a site. Parking areas, driveways, and common or open areas are shared. Lot sizes are reduced in size and typically are more irregular in shape. Clustering buildings in a centralized area minimizes land disturbance and requires less land area for the installation of utilities and construction of roads and streets.

Planning and designing “cluster developments” should begin by developing a prototype cluster(s) on paper for the desired unit type and site situation before addressing lot layout on the total project site. This avoids many of the pitfalls encountered in laying out roads first and then building lots. By working out the objective and problems of lot-street relationships in advance, you can more readily see opportunities to capitalize on the project site’s physical characteristics. For example, the site planner will have greater opportunities to minimize the project’s environmental impacts and maximize the aesthetics and amenities of the site.

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Roadway Design

***Roadway design** is a planning principle that can be used to reduce impervious surface cover by reducing the lengths and widths of roadways and cul-de-sacs.*

Key Benefits

- Minimizes storm water runoff and associated pollutants generated by reducing the amount of impervious surface cover.
- Reduces the cost of roadway construction and maintenance.

Planning Consideration

- Reduce overall street length by considering different site and road layouts.
- Reduce street width by using narrow street designs.
- Consider alternative cul-de-sac designs.

Discussion

In many communities, streets are designed and installed at a greater width than necessary. Implementing alternative street layouts can often reduce the total length of streets and significantly minimize the impervious surface cover of a development site. Therefore, site designers should evaluate different street and cul-de-sac layouts that will result in reduced lengths and widths. Site designers should also look for associated landscaping measures that will provide additional infiltration of storm water runoff discharging from impervious surface areas.

Streets and Cul-de-Sac Widths

Typically, streets are designed to accommodate two rows of traffic and a row of parked cars on either side of the street. To reduce the amount of impervious surface cover, residential and private streets within a development should be designed for the minimum required pavement width that is needed for travel lanes, on-street parking, and emergency vehicle access. Some alternatives for accomplishing these objectives might include:

- Reducing on-street parking to one lane.
- Implementing single lane, one-way loop roads.
- Eliminating parking on cul-de-sacs with less than 200 average daily trips and two-way loop streets with less than 400 average daily trips.
- Using parking bays to accommodate the parking requirements of local residents.

Using the above approaches allows for a substantial reduction in the amount of impervious surface cover.

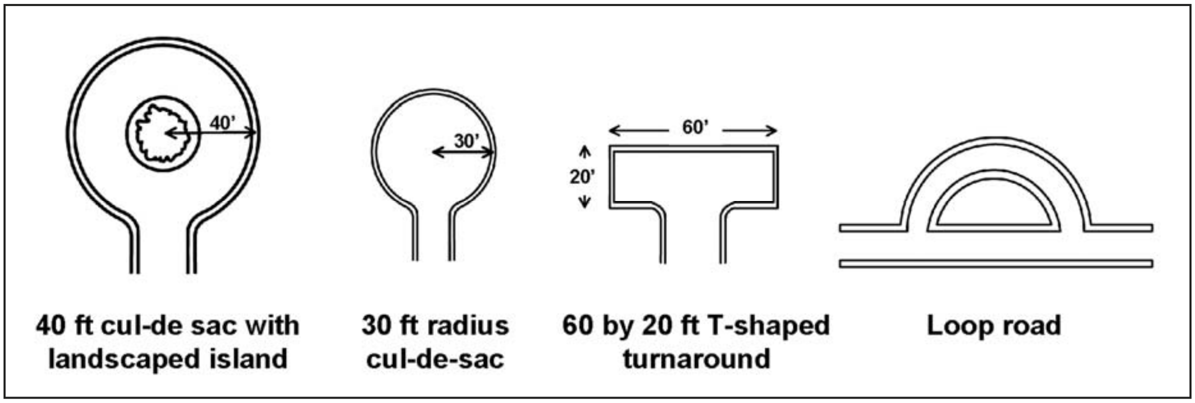
Turnarounds

Many cul-de-sacs and turnarounds have a radius of more than 40 feet. From a storm water management perspective, this creates a huge amount of impervious surface cover, increasing the quantity of storm water runoff. Therefore, to minimize the amount of impervious surface cover generated at a site, the size of cul-de-sacs and turnarounds should be reduced via alternative designs or eliminated altogether.

Providing enough turnaround area for different types of vehicles that may need to use cul-de-sacs and turnarounds is a significant aspect to consider in the planning and design process. For example, many vehicles like fire trucks, service vehicles, and school buses generally require a larger turning radius than passenger vehicles. In recent years some fire trucks have been designed with a smaller turning radius and some service vehicles are now equipped with triaxles which require a smaller turning radius. In regard to school buses, it is becoming commonplace for school children to board the bus at the intersection of the cul-de-sac and collector street rather than the bus entering the individual cul-de-sacs.

Many alternative cul-de-sac and turnaround designs generate less impervious surface cover than the traditional 40-foot cul-de-sacs. When planning and designing cul-de-sacs and turnarounds, use alternative designs to provide the minimum radii required to accommodate emergency and maintenance vehicles. Some of these alternatives include:

- Reducing the radius of cul-de-sacs to 30 feet.
- Creating hammerhead turnarounds.
- Using loop roads.
- Using pervious islands in the center of the cul-de-sac.



Source: Schueler, 1995

Some communities have specific planning and design criteria for streets, cul-de-sacs, and turnarounds. Therefore, altering street and cul-de-sac designs may require obtaining variances from the local plan department. In the future, local plan departments may be considering updates or modification of their local ordinances to allow for alternative designs.

Changing street and cul-de-sac designs may also require public information and outreach marketing strategies to educate the local residents about the environmental benefits of such design changes.

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Building Footprints

*The principle behind "**building footprints**" is to reduce the impervious footprint of commercial buildings and residences by constructing taller buildings while maintaining the same building floor-to-soil surface area ratio.*

Key Benefits

- Maximizes the amount of pervious surface area for storm water infiltration.
- Minimizes the amount of storm water runoff.
- Minimizes the amount of pollutants delivered to receiving waterbodies.

Planning Consideration

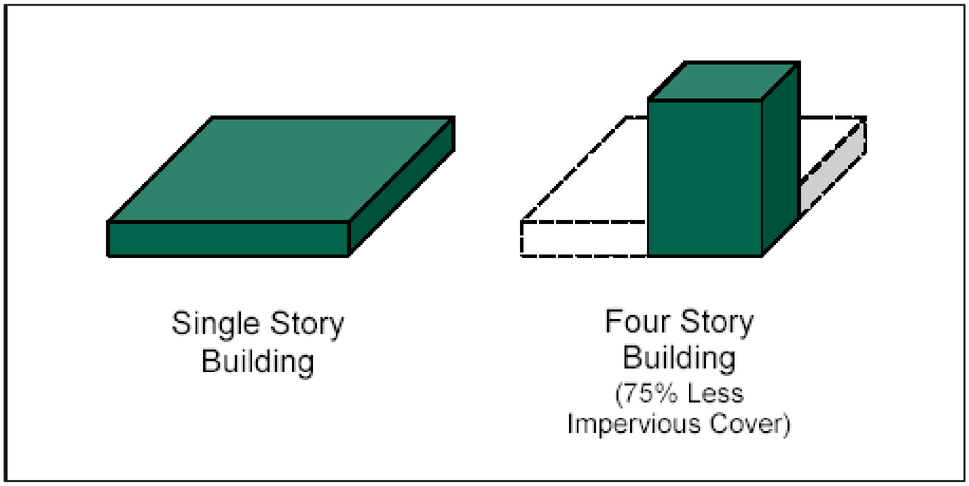
- Use building designs that are taller in order to reduce the impervious footprint of buildings.

Discussion

The building unit-to-lot relationship is a facet of site planning too often accepted as a "given," even though it offers a good opportunity to reduce runoff volumes, runoff velocities, and peak discharges. Planning and designing a development project should take into consideration the unit-to-lot relationship and attempt to match it to the existing site and hydrologic conditions.

Using alternative building designs and constructing taller buildings helps minimize the amount of impervious surface cover by reducing the building footprint and rooftop area.

Combining or consolidating the functions of a building or segmenting facilities can also be effective methods for reducing individual building footprints.



Source: Georgia Stormwater Management Manual, 2001

Parking Lot Footprints

*The principle behind "**parking lot footprints**" is to reduce the amount of impervious surface cover associated with parking lots.*

Key Benefits

- Reduces the amount of impervious surface cover.
- Reduces storm water runoff and amount of pollutants delivered to receiving waterbodies.

Planning Consideration

- Minimize the number of parking spaces.
- Reduce stall dimensions.
- Consider parking structures and shared parking.
- Consider using porous surfaces in vehicle overflow areas.

Discussion

Parking lots are often larger than necessary. This is due to the practice of designing for peak occupancy. As the following table shows, the number of parking spaces provided can often be reduced significantly if average parking demand numbers were used in the planning and design process.

Conventional Minimum Parking Ratios

Land Use	Parking Requirement		
	Parking Ratio	Typical Range	Actual Average Parking Demand
Single family homes	2 spaces per dwelling unit	1.5–2.5	1.11 spaces per dwelling unit
Shopping center	5 spaces per 1000 ft^2 GFA*	4.0–6.5	3.97 per 1000 ft^2 GFA*
Convenience store	3.3 spaces per 1000 ft^2 GFA*	2.0–10.0	-----
Industrial	1 space per 1000 ft^2 GFA*	0.5–2.0	1.48 per 1000 ft^2 GFA*
Medical/dental office	5.7 spaces per 1000 ft^2 GFA*	4.5–10.0	4.11 per 1000 ft^2 GFA*

*GFA = Gross floor area of a building without storage or utility spaces.

Source: U.S. EPA, 2005, Using Smart Growth Techniques (Adapted from Institute of Transportation Engineers, 1987; Smith, 1984; Wells, 1994)

There are several methods that can be used to minimize impervious surface cover associated with parking lot footprints. Some of these methods are:

- Setting maximum sizes for parking spaces.
- Minimizing parking stall dimensions.
- Providing spaces for compact cars.
- Incorporating efficient parking lanes.
- Constructing multi-level parking structures.
- Sharing parking lots.
- Installing alternative porous surfaces in overflow parking areas.

One of the easiest and least costly methods of reducing parking lot footprints is adjusting the size of individual parking stalls. Reducing the length and width of parking stalls can greatly reduce the size of parking lots. Designing parking lots with areas and parking stalls designated for specific types of vehicles, such as compact cars or sport utility vehicles, can provide for an efficient use of space.

Parking structures can also have a huge impact on the reduction of the overall parking lot footprint.

Shared parking is a method that works well in mixed use areas. For example, an office complex where employees work daytime hours throughout the week may share a lot with a church which typically meets on weekends and evenings.

Installing porous or permeable surfaces in parking lot overflow areas is an effective method for minimizing the amount of storm water runoff generated from these areas. These systems can be used in both new development and redevelopment/retrofit projects.

Source: Georgia Stormwater Management Manual, 2001

Porous paver or porous pavement systems are well suited for use in parking lot overflow areas. Porous pavers consist of structural units which have voids filled with a pervious material such as sand or gravel. Porous paver systems can be vegetated so that the paver system is inconspicuous or they can be left visible to the public. Porous pavement systems include porous asphalt and pervious concrete. These systems have an advantage over conventional asphalt and concrete because they allow storm water runoff to be stored and treated.

Proper installation and maintenance of porous paver and pavement systems is essential if they are to perform properly. These systems do require more maintenance than conventional asphalt and concrete parking areas.

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Setbacks & Frontages

*The principle behind "**setbacks and frontages**" is to reduce the total length of impervious streets and driveways.*

Key Benefits

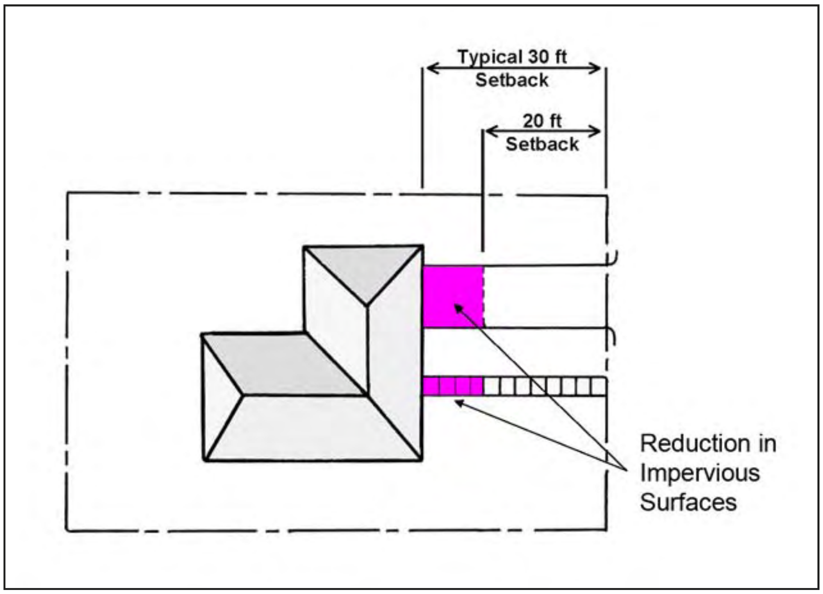
- Reduces the amount of impervious surface cover.
- Reduces the amount of storm water runoff and the amount of pollutants delivered to receiving waterbodies.

Planning Consideration

- Reduce front and side setback distances for homes and buildings.
- Use narrower frontages.

Discussion

The reduction of setback and frontage distances will reduce the amount of impervious surface cover associated with a development site. For example, on residential and commercial developments, shortened setback distances reduce the amount of impervious cover from driveways and entryways. A setback of 20 feet is generally sufficient for parking a vehicle in a driveway without infringing on the public right-of-way. Reducing a setback distance from 30 feet to 20 feet can reduce driveway and sidewalk impervious surface cover by 30 percent or more.



Source: Adapted from Minnesota Pollution Control Agency, Protecting Water Quality in Urban Areas, 1989; and Georgia Stormwater Management Manual, 2001

As shown in the photograph of this measure, minimizing side yard setbacks and using narrower frontages can significantly reduce impervious surface cover and total street lengths. This is especially important in cluster developments and open space designs.

Natural Drainageways vs. Storm Sewers

This principle takes advantage of ***natural drainageways*** *by incorporating them into a project's storm water management system.*

Key Benefits

- Lowers the expense of road and storm sewer construction as well as the need for land disturbance and grading.
- Maintains natural storm water runoff storage, infiltration, and treatment.
- Storm water filtration and infiltration occurs when it is used with buffer systems.
- Provides for longer travel times and lower peak discharges of storm water runoff than hydraulically efficient man-made channels.

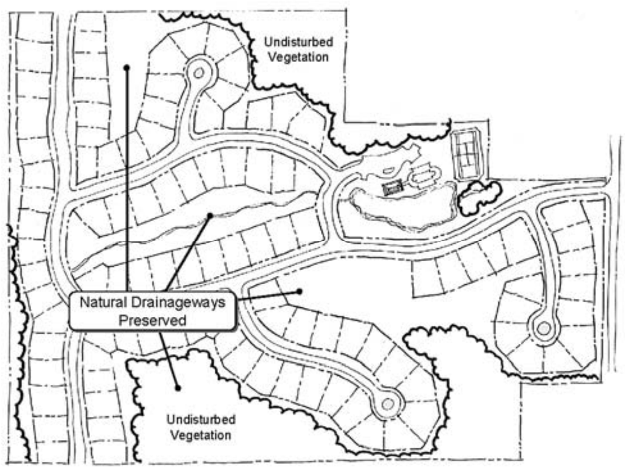
Planning Consideration

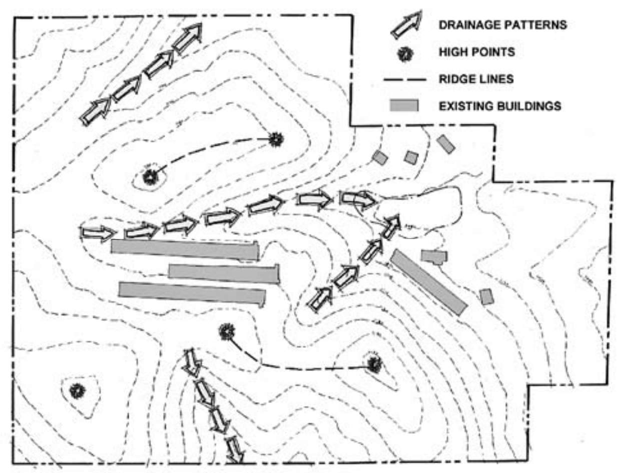
- Preserve natural flow corridors.
- Direct runoff to natural drainageways, ensuring that peak flows and velocities will not cause channel erosion.
- Use vegetated channels (enhanced wet or dry swales or grass channels) in place of curb and gutter to convey and treat storm water runoff.

Discussion

Natural drainage features such as creeks and streams that flow through or are adjacent to a project site are an amenity that can add aesthetic value to the property and therefore should be incorporated into the project design and layout. Incorporating natural drainageways into the project's drainage system also helps minimize the cost of the project by reducing grading costs, the investment in man-made drainage structures, and installation of the drainage system.

Storm sewers and other structural drainage systems are generally used in urban development projects to convey storm water runoff in the most efficient manner. Using these man-made systems increases storm water runoff, runoff flow velocities, and delivery of pollutants to the receiving water body. The alternative to this approach is to use constructed drainageways and vegetated swales to carry the storm water. In low-density developments and subdivisions, drainageways are well suited for removing storm water runoff pollutants, allowing filtering and infiltration of runoff, lowering peak flow discharges, providing higher storage capacities, and reducing the velocity of storm water runoff.





Source: Georgia Stormwater Management Manual, 2001

Planning, Design, and Layout

Incorporating natural drainageways into a site plan requires identifying natural drainage patterns such as overland flow and swales and conveyance systems where water will concentrate. Where possible, these natural drainage features should be integrated into the location and design of storm water management measures, especially around critical areas where water will concentrate. Natural drainage features should also be used to convey storm water runoff over and off the site to avoid the expense and issues associated with constructing an artificial drainage system.

Drainage System

The planning and design of a project's primary drainage system must take into consideration expected storm water runoff volumes and velocities from the final land use. It is critical that the drainage system be planned and designed to accommodate increased runoff from the project site. It is also critical to design a conveyance system that will be resistant to the erosive forces created by increased storm water runoff volumes and velocities.

At this stage of planning and design, it is often advantageous to begin evaluating potential sites for detention/retention ponds.

Secondary Drainage System

Secondary drainage systems associated with a project site also require careful evaluation. Where feasible, choose natural or constructed, vegetated drainage swales over a conventional storm sewer system and curbs and gutters. Existing natural drainage swales or constructed grass-lined swales are much more effective in regulating water quality and quantity and are less expensive to construct and maintain than a conventional storm sewer system.

As with the primary drainage system, it is critical that secondary, man-made conveyance systems be properly designed to accommodate expected runoff from the final land use. Again, these secondary, man-made systems will need to be properly stabilized to reduce the erosive forces of storm water runoff. If it is anticipated that runoff flows will increase, route the augmented flow into a man-made storm water conveyance system or detention area and preserve the natural storm water conveyance system.

Natural conveyance systems often have an adjoining floodplain which is used to temporarily store excess storm water runoff and reduce downstream flooding potential. Wherever possible, construction activities and development in floodplains should be avoided. In many instances, floodplains and natural riparian buffer zones can be integrated into the project design to create a level of aesthetic value and/or used as a natural or recreational area. It is also important to preserve natural areas where storm water runoff flow enters the drainage system.

When incorporating natural drainageways into a project's drainage system, it is important to install storm water management measures that will ensure downstream drainageways are protected from erosion, degradation, and high post-development flows from project site storm water discharges.

Occasionally the site designer will propose moving or relocating a natural drainageway. It is important to note that modification or relocation of natural drainageways requires a high level of coordination and generally requires the use of sophisticated storm water quality measures to prevent the discharge of sediment and other pollutants associated with the construction activity. Relocation of natural drainageways can be a costly venture, even if done correctly, and usually requires permits from state and/or federal agencies.

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Storm Water Pollution Prevention Plan

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Site designers/planners and engineers typically pay very close attention to all phases of a construction project. However, the same attention is not always given to storm water management. In fact, it is often overlooked.

This section of the storm water manual outlines and describes a recommended step-by-step process for developing a storm water pollution prevention plan. It is intended as a guide and procedures are written in general terms to be applicable to all types of projects. Site planners and regulatory authorities are urged to become familiar with the contents of this section of the manual.

Once the site designer has completed the initial site assessment, planning, and design process, he or she can begin developing a set of detailed construction plans for the project. Construction plans are a blueprint for the project site. They identify resource issues; describe operational procedures; provide information in regard to project design and layout; identify areas of clearing, grading, and construction limits; and provide information in regard to the installation and maintenance of infrastructure. The content of a construction plan is described in more detail in Chapter 3.

One very important element of a construction plan is a storm water pollution prevention plan. A storm water pollution prevention plan is a working document that serves as a blueprint and principal site reference for the location, design specifications, installation criteria, construction schedule, and maintenance of all storm water quality measures. The plan should be part of the general construction plan and not a separate document because all activities that occur on a project site are interrelated. Changes to one or more aspects of the construction plan can drastically affect elements of the storm water pollution prevention plan and vise versa.

The purpose of a storm water pollution prevention plan is to establish which storm water quality measures will be used to minimize the discharge of pollutants from the project site. Selection of storm water quality measures should focus on the pollutants that are associated with the construction phase of the project as well as the reduction of the pollutants that will be associated with the final post-construction land use. In order to choose the appropriate measures, the plan designer should have an understanding of the project site, pollutants associated with construction and the intended land use, and the sources that generate the pollutants.

Chapter 3 provides a summary of items that should be included in storm water pollution prevention plans. However, it is important to recognize that the content of the storm water pollution prevention plan may vary from one regulating entity to the next because of differences in local ordinances and regulations. Therefore, plan designers should become familiar with the requirements and expectations of each entity having regulatory authority over the project.

As noted above, a storm water pollution prevention plan identifies storm water quality measures that will be used to minimize the discharge of pollutants. Storm water pollution prevention plan drawings should identify where each storm water quality measure is located in the landscape; provide construction details, dimensions, and design specifications for each measure; and provide instructions for the proper installation and maintenance of each measure. Information and drawings provided for each storm water quality measure should be clear, concise, and contain enough detail so that on-site contractors and personnel can install the measures according to accepted industry standards and specifications. Chapters 7 and 8 of this manual provide detailed information in regard to proper installation and maintenance of a variety of storm water quality measures. Proper incorporation of this information into construction plans and, in particular, the storm water pollution prevention plan will assist site designers in addressing the discharge of pollutants associated with construction activities and post-construction land uses.

A very important aspect of storm water pollution prevention plans is the schedule for implementation of each storm water quality measure. Measures will not be effective if they are not installed at appropriate times during the construction process. Most measures should be installed before grading and land disturbance is initiated on active areas of the project site. To meet this objective, storm water pollution prevention plans should contain a construction sequence schedule component.

Construction sequence schedules are a critical element of storm water pollution prevention plans. The sequence of construction is not necessarily a specific date when each storm water quality measure will be implemented, but rather a description of when each measure will be installed in relation to grading and land-disturbing activities. Construction sequencing is time sensitive and requires planning and coordination between all individuals involved with the construction project. The "Development of a Construction Sequence Schedule" section in Chapter 5 provides insight and guidance into the development of a construction sequence schedule.

Another key element of a storm water pollution prevention plan is a quality assurance plan. Quality assurance plans provide guidance and establish procedures for monitoring the construction site and inspecting storm water measures to ensure they are maintained and functioning properly. The "Developing and Implementing a Quality Assurance Program" in Chapter 6 provides an in-depth explanation and insight into developing and implementing a quality assurance plan.

In addition to the above, Indiana's storm water rule for runoff associated with construction activity, found in the Indiana Administrative Code under Title 327, Article 15, Chapter 5 (327 IAC 15-5), has a requirement that storm water measures be inspected by the end of the next business day following each measurable storm event (defined as a precipitation event that results in total measured precipitation accumulation equal to, or greater than, 0.5 inch of rainfall) and at a minimum of one time per week. Some local ordinances may require more frequent inspections than those required in 327 IAC 15-5.

Inspection frequency intervals and maintenance criteria are unique to every storm water quality measure. Inspection frequencies are generally based on the overall performance of the measure. Some measures require daily inspections whereas others may require, at a minimum, weekly inspections. Each storm water quality measure contained in this manual has been assigned an inspection frequency.

To meet regulatory requirements and storm water quality measure design standards and specifications, a quality assurance plan should identify an inspection schedule for each measure identified in the storm water pollution prevention plan.

There are several valuable resources, including individuals knowledgeable about storm water issues and erosion and sediment control, which can be utilized when developing a storm water pollution prevention plan. Resource information and technical assistance is available from Indiana's local soil and water conservation districts, the Indiana Department of Natural Resources, the Indiana Department of Environmental Management, the U.S. Department of Agriculture's Natural Resources Conservation Service, and city or county engineering staffs. Private environmental and engineering firms are also a valuable resource.

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STORM WATER POLLUTION PREVENTION PLAN DEVELOPMENT

Up to this point, the site designer has conducted a site assessment and data collection process, analyzed the data, and begun to formulate an overall site design and layout of the project. Using the existing project site data and information that has already been collected and analyzed, the project planning principles in Chapter 4 of this manual, and the construction plans that have been developed to this point, the site designer can now begin to develop a storm water pollution prevention plan.

The goal of any project is to manage storm water runoff and minimize the off-site discharge of pollutants. During the construction phase the focus is on minimizing erosion and sedimentation. However, there are other potential pollutants associated with construction. These pollutants include but are not limited to fuel and construction waste. Appropriate project management and storm water quality measures will need to be implemented to minimize potential off-site pollutant discharges and to reduce the potential impact these pollutants may have on soil and water quality. In regard to post-construction land uses, the focus should be on the reduction of pollutants generated from the type of land use and minimizing the discharge and impacts of storm water runoff pollutants to receiving waters.

Storm water pollution prevention plans are a critical tool for achieving the above goals and objectives. They typically contain a wide array of storm water quality measures designed to protect water quality. On most project sites, these measures need to be implemented and maintained throughout the life of the construction project. It is also important to recognize that several post-construction measures can be incorporated into the early phases of a project and used in the control and management of sediment. These post-construction measures can later be modified or adapted to reduce the impact of pollutants or runoff quantity associated with the post-construction land use.

As site designers begin to make decisions regarding the selection of storm water quality measures for the treatment of construction and post-construction storm water runoff, it may be necessary to make adjustments to the overall site design. This may require re-evaluating previously developed plans and documentation that was collected in earlier stages of the planning process. In situations where the site designer is restricted by the overall site design, the selection of storm water quality measure alternatives may be limited. In addition, the measures chosen may be more expensive to install and have higher maintenance requirements and costs. For these reasons, it is very important that site designers make every effort to prepare the project design and layout simultaneously with the development of the storm water pollution prevention plan.

As previously discussed, storm water pollution prevention plans should address pollutants associated with or that may be associated with the project site during construction and post-construction land use. With this concept in mind, storm water pollution prevention plans can be divided into two distinct components: (1) an erosion and sediment control plan and (2) a post-construction pollution prevention plan.

Erosion & Sediment Control Plan

The primary purpose of an erosion and sediment control plan is to minimize sedimentation because this is the principle pollutant associated with construction activity. However, other pollutants are also associated with construction activities. Management of these pollutants is just as important as minimizing sedimentation. If these pollutants are not appropriately controlled, they can have a detrimental impact to soil and water quality. Although referred to as an erosion and sediment control plan, the plan should include provisions that address the management of other pollutants associated with construction activities.

Assessment of Project-Specific Pollutants Associated With Construction Activities

Before selecting any storm water quality measure, it is important to identify the pollutants that will be associated with construction activities. Most construction activities will include clearing and grading. Clearing and grading leaves soil vulnerable to rain and storm water runoff and results in increased erosion and sedimentation. Therefore, sediment is the primary pollutant associated with construction activities.

In addition to sediment, construction activities may include operations that generate other pollutants. The presence of these pollutants will be directly related to the type of construction activity and operations that will take place on the construction project. Activities at the site that may generate pollutants include but are not limited to construction vehicle operation and maintenance (e.g., fueling and changing of hydraulic fluids and oils); concrete washout; improper storage of construction materials; improper disposal of construction trash and debris; improper application or overapplication of fertilizers and pesticides; and improper storage, application, and disposal of soluble materials or other materials that can be mobilized by storm water runoff. Chapter 1 of this manual provides more information about the types of pollutants associated with urban development and their impacts on water quality.

Site Management & Planning Principles

When developing an erosion and sediment control plan, it is not uncommon to focus, or place primary emphasis on, the selection of specific storm water quality measures designed for the prevention of erosion and control of sediment and overlook a site's physical characteristics which can have a major impact on site planning and management.

Site management techniques such as phasing land-disturbing activities, minimizing the area of soil exposed to the forces of erosion, incorporating natural features of the site into the project design, and using vegetative and mulching practices can significantly reduce a project's construction costs and the impacts it will have on the local environment. When incorporating the above principles into a storm water pollution prevention plan, an assessment should be made with regard to how these principles will affect the selection of storm water quality measures and what affect they will have on the effectiveness of the measures.

Planning and site management techniques can generally be implemented with little or no cost and therefore are as important as the storm water quality measures chosen for the project. By now it should be evident that site planning and management is a critical component of a construction project and can have a significant affect on overall project costs and the effectiveness of erosion, sediment, and storm water runoff control measures. Following is a brief discussion in regard to several site planning and management principles that should be considered and, where applicable, applied to a project site before selecting any storm water quality measures. It is important to note that the list provided here is not all inclusive.

Retain Existing Vegetation on the Construction Site

Vegetation is a valuable asset on construction sites and a concerted effort should be made to retain existing vegetation whenever possible. A healthy, dense stand of existing vegetative cover will reduce erosion, reduce storm water runoff velocities and volumes, and filter and trap solids suspended in storm water runoff. Existing vegetative cover can be used as a filter zone. The vegetative filter must be of sufficient width and must have a soil surface cover density of 80 percent or more.

Tree selection and preservation can also add value to a project site. They can serve as useful buffer zones and can increase the value of the property by providing an aesthetic feature that prospective property buyers are often willing to pay for.

When developing an erosion and sediment control plan, the plan designer should revisit the project site to verify that the conditions observed at the time of the site assessment and data collection phase have not changed from the original assessment.

Establish Vegetation on the Construction Site

Vegetation is the most efficient and economical form of erosion control. On active construction sites it is generally cheaper to stabilize an unvegetated area than to repair rills and gullies caused by erosion. It is also easier to prevent or control erosion than trying to trap soil particles that have become suspended in storm water runoff.

Areas void of vegetation or that have crop residue that will decompose should be stabilized as soon as possible. Stabilization can be achieved through the application of temporary or permanent vegetative cover. As a general rule of thumb, temporary seeding should be applied to areas that are scheduled or will likely be left idle for an extended period of time up to one year. Permanent seeding should be applied to all areas that are at final grade, phased projects where each subsequent phase will not be started for a period of eight months or more, and areas scheduled to be idle for a period of one year or more.

Vegetation can also be used as a filter medium around the perimeter of the project site and other key areas on the project site. To effectively remove pollutants from storm water runoff, the vegetative filter must be of sufficient width and well established with a vigorous, dense (80 percent or more vegetative cover over the soil surface) stand of vegetation.

Phase Project Activities

Minimizing the amount of land left exposed to the forces of erosion is an effective method for reducing erosion and sedimentation. Unfortunately, this is often difficult due to the nature of construction operations. Phasing of project activities is one method of minimizing the amount of soil exposed at any one time. This principle works especially well on large projects.

Limits of clearing and grading should be determined during the planning phase of a project. Decisions should be made to determine which areas must be cleared and graded in order to accommodate immediate construction activities, while paying special attention to critical areas and environmentally sensitive areas that must be protected. To minimize the extent and duration that soil is exposed to the forces of wind and water erosion, temporary or permanent seeding should be applied to all inactive areas of a project site where vegetation is sparse or non-existent.

Whenever possible, clearing and grading should be limited to active areas of construction and only progress as each new project construction area is started. Land-disturbance activities such as mass clearing and grading should be avoided. It is important to recognize that recreational grading does not serve a purpose and can add significant costs (e.g., fuel, personnel salaries, installation of additional storm water measures, increased maintenance of storm water measures, etc.) to a project.

Appropriate erosion and sediment control measures **must** be installed and operational prior to initiating clearing and grading.

Revegetate or Stabilize Disturbed Areas Immediately

Grading should be completed in the shortest period of time possible and areas stabilized immediately after completion of grading operations. Stabilize areas using measures such as temporary or permanent seeding, sodding, mulching, erosion control blankets, or other measures that will protect the soil surface. Areas that can be graded to finished elevations should be permanently seeded.

Manage Construction Traffic Flow and Staging Areas

Provide access for all construction traffic by establishing stable construction ingress and egress points. Establish staging areas and provide stable areas for on-site personnel to park their vehicles. Carefully plan the flow of construction traffic and plan construction traffic routes that will avoid vegetation that is to be preserved and newly planted areas.

On sites that require the use of on-site sewage disposal facilities or will utilize storm water infiltration measures, locate staging areas, parking areas, and construction traffic routes outside the limits of areas designated for these uses. This will prevent soil compaction and maintain the integrity of the soil's infiltration capacity.

Employ Management Measures to Control Pollutants Other than Sediment

Sediment is just one of many pollutants associated with construction activities. Examples of other pollutants include petrochemicals (e.g., oil, gasoline, asphalt), herbicides, solid wastes (e.g., wood, metal, roofing materials), construction chemicals, waste water, and fertilizers.

Many pollutants attach themselves to soil particles and are carried off-site when the soil particles become suspended in storm water runoff. However, on-site containment of all pollutants may not always be feasible if water soluble pollutants are present or the pollutants are attached to fine clay particles. The removal of clay particles is based on the detention time of the measure and will dictate the efficiency of the measure to remove the suspended soil particles. Site management techniques such as proper use, storage, handling, and disposal procedures are generally the most effective method for minimizing the discharge of these pollutants from a construction site. On most construction projects the responsibility of properly managing these pollutants will rest on the shoulders of the contractors and subcontractors working on the site.

Most people involved with construction activities fail to recognize that solid wastes generated at the site are a pollutant. Appropriate solid waste receptacles should be provided at every construction site to allow for the proper disposal of waste and debris. On individual building sites, the project site owner may require individual builders/contractors to provide receptacles for the disposal of their waste building materials and products. This requirement is typically part of the restrictive covenants, included in the sales contract, or a provision in the storm water pollution prevention plan. It is imperative that the project site owner establish requirements and procedures for proper handling and disposal of pollutants associated with the project and that he or she clearly conveys this information to each builder/contractor and informs them of their responsibility to properly dispose of construction waste and debris.

Hazardous materials are another potential pollutant that must be properly handled, stored, and disposed of on construction sites. According to federal and Indiana statutes, the term "hazardous waste" means a solid waste, or combination of solid waste that, because of its quantity, concentration, or physical, chemical or infectious characteristics may: (1) cause or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or (2) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed. Hazardous waste materials not only pose a threat to receiving waters, but some can percolate into the soil resulting in contaminated soil which may have to be excavated and transported to a hazardous waste disposal facility or may require expensive bioremediation treatment at the project site. Hazardous waste materials should be securely stored in a shed, trailer, or building that can be locked to prevent vandalism or unauthorized access. Contractors and other on-site personnel must comply with hazardous wastes storage and disposal regulations administered by the Indiana Department of Environmental Management, Office of Land Quality.

Construction vehicles and equipment are the source of several potential pollutants associated with a construction site. Maintenance of vehicles should be done in a properly equipped shop, not at the construction site. All petroleum storage tanks should meet state regulatory requirements for containment to prevent spills, leaks, and other discharges from coming in contact with the soil and ground water. Materials and equipment needed for cleanup procedures should be kept readily available on the project site, either at an equipment storage area or on the contractor(s) vehicles.

Include Provisions to Address Independent Activities that Occur on the Project Site

Many projects include activities that are conducted by independent entities not under the direct control of the project site owner. These entities include but are not limited to utility companies and independent builders. It is in the best interest of the project site owner to coordinate with these entities to ensure that each is aware of the provisions of the storm water pollution prevention plan and that they understand their responsibility for erosion and sediment control and site management as it relates to the activities they are conducting on the project site.

Where possible, utility installation should be scheduled in advance and built into the overall sequence of construction for the project. Utility locations should be predetermined so that installation will not interfere with the location of storm water quality measures. Again, representatives of utility companies should be aware of the provisions of the storm water pollution prevention plan and should have a clear understanding as to who will be responsible for erosion and sediment control and final stabilization as it relates to their construction activities.

Construction on individual building lots creates an additional challenge on development projects. Building construction usually occurs after all infrastructure, including storm sewers, have been installed and are functioning. Sediment yields can be extremely high on projects with a high concentration of building activity. This situation is more common on residential sites due to the number of and size of active building lots. In addition, there are a large number of contractors and subcontractors working on a site at one time. Every plan should contain provisions for erosion and sediment control on individual building lots. The provisions for erosion and sediment control should also be clearly explained to each builder and provided in writing. To ensure their compliance with local and state regulations, some development companies specify conditions for erosion/sediment control and pollution prevention in their sales contracts or through performance bonds.

Manage Dust Control

Land that has been disturbed and left void of vegetative cover is vulnerable to the forces of wind and water erosion. Every effort should be made to prevent or control the generation of dust and wind blown particles. Dust can be generated by wind blowing across the soil surface or by vehicles and construction equipment traveling across the project site. Construction site management techniques should employ the use of basic dust control measures designed to reduce the overall impact of dust generation. Watering the soil surface, establishing vegetative cover, and the application of soil bonding agents are just a few examples of dust control techniques that can be deployed on a construction site.

Selection of Storm Water Quality Measures Associated with Construction Activities

Several criteria must be considered when selecting storm water quality measures. One of these criteria is identifying potential areas that are or will be subject to erosion and the discharge of sediment. Some of these areas should have been identified during the site assessment and data collection process. That information should be reviewed and adjustments made as the planning process proceeds. Areas subject to erosion and the off-site discharge of sediment should be identified on a map.

Selection of storm water quality measures should be based on the potential pollutants associated with the project. Effective management and treatment of storm water runoff requires storm water quality measures to be applied to the correct field situations, designed according to site conditions, installed correctly and at the appropriate time, and maintained.

Watershed sizes and associated information is critical when calculating storm water runoff volumes, assessing erosion potential, estimating sediment yields, and selecting and designing appropriate storm water quality measures. Therefore, watersheds and drainage areas must be determined before the site designer can select, size, and design individual storm water quality measures.

Major watersheds and drainage areas associated with the project site should have been identified at the time of the project site assessment and data collection process. Delineation of drainage areas will help identify the direction of surface water flow. Often, watershed boundaries will extend up slope or down slope of the actual project site boundaries. Working with large drainage areas and an entire project site can be overwhelming. It is generally easier to work with smaller drainage areas than trying to address the overall site. Smaller drainage areas are more manageable units when predicting storm water runoff volumes and selecting control measures. Smaller drainage areas also allow the site designer to select from a larger variety of storm water measures. If a delineated watershed exceeds five acres, the plan designer should attempt to subdivide the watershed into smaller drainage areas.

All storm water quality measures have performance limitations, whether it is trapping efficiency for the targeted pollutant(s) or limitations in appropriately handling the volume of storm water runoff. It is also important to keep in mind that many storm water quality measures have design and application parameters well under the five acre threshold. In fact, the design and application of many measures are typically for one or two acres.

When selecting storm water quality measures, the site designer needs to be cognizant of the dynamics of construction activities. As land-disturbing activities take place, drainage areas may increase or decrease. To compensate for the changes in drainage area size, storm water measures should be selected for the most extreme field conditions. If this is not feasible, an alternative is to identify several measures that can be installed as drainage areas change. This approach will require good communication and coordination with earthmoving contractors.

When selecting measures it is important to consider the consequences of failure. Failure of a measure may result in damage to adjacent properties and water resources.

The first instinct when trying to address erosion and sediment control is to install sediment control measures. Sediment control measures either filter storm water runoff or hold it temporarily to allow soil particles to settle out. It is very difficult to trap sediment with sediment control measures because they have limited trapping efficiencies even when they are performing at their highest level. Sediment will be a consequence of all land-disturbing activities. Therefore, sediment control measures should always be included as part of the storm water pollution prevention plan. However, every plan should also focus on the use of erosion control measures that can be used to minimize the generation of sediment.

Erosion and sediment control measures should be installed as a system. An erosion and sediment control system consists of using multiple measures, in a series, which minimizes erosion and traps or removes suspended sediment from storm water runoff discharges. It is not prudent to rely on a single sediment control measure at the point of discharge. Using multiple measures to minimize erosion and treat sediment-laden storm water runoff will increase the overall efficiency of the erosion and sediment control system and often allows for the use of smaller, less costly measures. For example, it will be much more cost effective to install a variety of erosion and sediment control measures throughout the drainage area than trying to treat the entire drainage area with a single sediment basin at the point of discharge. A well-planned erosion and sediment control system will have an aggressive stabilization plan and provide for the installation of sediment control measures, not only on the site's perimeter but throughout the entire drainage area.

Erosion and sediment control measures are usually a combination of structural and nonstructural measures. They may be temporary and function only during the construction phase or they may be permanent and become part of the completed development. Although the primary focus during this phase of plan development is erosion and sediment control, it can be beneficial to consider post-construction measures as well. It is important to understand that planning post-construction measures during this phase is usually more effective than trying to retrofit a site after all decisions have been made.

Storm water quality measures associated with construction activities can be divided into three major groups (i.e., erosion control, runoff control, and sediment control) with the primary focus on erosion and sediment control. Erosion control is typically achieved through surface stabilization. Runoff and sediment control is typically achieved through the use of more substantial and costly structural measures.

Erosion Control

The most effective sediment control method is to prevent erosion. Measures that prevent or minimize erosion are called erosion control measures.

Erosion control is often thought of as an annoying proposition and difficult to implement when numerous construction activities are occurring simultaneously at a construction site. Erosion control is usually achieved through the establishment of vegetation or the application of nonerosive materials to the soil surface. Based on this definition, most construction industry personnel usually view this activity as occurring near the completion of the project and do not consider it as an option during construction. However, erosion control is one of the most effective tools available to control sediment. Effective implementation of an erosion control program often requires a change in the perceptions and attitudes of construction site personnel and managers. It will also change the way a construction project is managed and will require a high degree of planning and coordination between site managers, planners, contractors, subcontractors, and others involved with the project.

Erosion control is the first line of defense in protecting water quality at a construction site. Reducing erosion at the source is much more effective and efficient than trying to trap suspended sediment in surface water runoff. Erosion control is achieved by protecting the soil surface from raindrop impact and overland flow of storm water runoff. An effective erosion control program will initially control sheet and rill erosion and minimize gully and channel erosion.

Surface stabilization is achieved through the application of nonerosive materials to the soil surface. Common forms of erosion control are seeding, sodding, mulching, riprap, or application of other nonerosive covers. Effective surface stabilization will minimize erosion and the generation of sediment and can achieve efficiency levels as high as 90 percent to 95 percent.

All erosion and sediment control plans should include an aggressive stabilization program. A well-planned stabilization program is essential and should be implemented throughout the life of the construction project. Vegetative cover is relatively inexpensive to achieve and is often the most practical long-term solution to stabilization. Incorporating an effective stabilization program into the project reduces cost, minimizes maintenance and repair, and makes structural erosion and sediment control measures more effective and less costly to maintain.

The first step in developing an effective erosion control program is to evaluate the slope to be treated and to identify the type of erosion that has occurred or that will potentially occur in an area. Erosion is typically categorized as raindrop, sheet, rill, gully, channel, and shoreline. Areas that are subject to raindrop, sheet, and rill erosion will be addressed differently than runoff that is being conveyed in a channel. Streambank and shoreline erosion from variable water levels and wave action may require a totally different approach. The second step in developing an effective erosion control program involves selecting appropriate methods to control erosion. When selecting a stabilization method, the plan designer should always consider establishment requirements, adaptability to site conditions, aesthetics, and maintenance requirements.

Surface stabilization methods can be categorized as either temporary or permanent. Temporary stabilization includes the application of a fast-growing seed such as wheat or rye and/or the application of a mulch material. Mulch materials must be appropriately anchored to the soil surface to reduce their potential for being blown away or carried away by storm water runoff. Permanent stabilization is the most effective means of erosion control. Permanent stabilization should be utilized where areas are at final grade or where activity will not occur for a period eight months or more.

There is a general misconception that permanent stabilization can only be used when a project's construction activities are complete and all areas are at final grade. In reality, permanent stabilization methods can be used throughout the life of a project. For example, permanent stabilization can be applied to any area at final grade, including drainage swales and the side slopes of basins.

The application of temporary and permanent surface stabilization depends on several factors such as time of the year, the length of time unvegetated areas will be left idle, phasing of land-disturbing activities, and sequencing of land-disturbing activities. Waiting until project construction activities are complete is not an effective approach to surface stabilization as it leaves large areas of soil material exposed to rainfall, the forces of erosion, and the need for a more intensive sediment control program.

Permanent stabilization is typically thought of as permanent seeding. However, there are several other methods including the use of riprap and other hard armor. Vegetative controls are generally preferred and the most cost-effective method of permanent soil stabilization. While many plan designers feel there is a clear line between the use of vegetation and hard armor, the industry has many alternatives available that expand the options for using vegetative cover. For example, there are a number of erosion control blankets available commercially that provide a stable environment until seed can become established thereby reducing the need for hard armor. In addition, there are synthetic blankets and turf reinforcement mats that increase the stability of vegetation once it becomes established. Site designers should evaluate and assess the applicability of these options and make a concerted effort to reduce the use of hard armor and other impervious materials.

A stabilization program can be divided into three categories: 1) phased stabilization, 2) incremental stabilization, and 3) final stabilization.

1) Phased Stabilization

There are two distinct categories of phased stabilization. The first category covers projects involving phased construction over several years. For example, if a project site owner plans to develop Phase I of a project with the intent of developing Phases II and III at a later date, it would be in the best interest of the project site owner if the site designer develops a stabilization plan that will adequately protect Phases II and III until such time as they are developed. The site designer's first decision is to identify the existing vegetative cover associated with these areas. If the entire area is pastured and has a good vegetative cover, additional measures may not be required. However, if the site includes areas that are void of vegetative cover or includes crop residue, the plan should specify that these areas be properly prepared and stabilized using an appropriate method of surface stabilization. Stabilization of these areas can be accomplished through a variety of seeding methods that result in minimal disturbance of the soil surface. One such method is applying seed with a no-till drill.

The second category of phased stabilization is applicable to projects where construction or land-disturbing activities are planned in small, workable units. In this scenario, surface stabilization is applied as construction is completed and progresses to the next designated area. Waiting until the project is complete is not an effective approach as it leaves large areas of soil exposed to the forces of erosion and requires implementation of a more intensive sediment control program.

2) Incremental Stabilization

Incremental stabilization is similar to phasing but occurs on a smaller scale. Incremental stabilization involves the establishment of vegetative cover or the application of nonerosive cover as work progresses.

Incremental stabilization is well suited for projects requiring extensive cut and fill operations. On these types of projects, as cut slopes are excavated and fill slopes are brought to grade, the slopes can be stabilized with each 10 foot of cut or fill. Another example is the cutting of a conveyance channel. The channel can be stabilized as work progresses on cutting the channel grade.

To maximize the effectiveness of erosion and sediment control systems, site designers should carefully evaluate land-disturbing activities and incorporate an aggressive stabilization program into the plans. A common excuse for not stabilizing areas on a construction site is that additional work is planned for the area. Whether a site is at final grade or not, areas should be stabilized as grading operations are completed. Incremental stabilization works well in these situations.

3) Final Stabilization

Final stabilization is typically associated with closure of a project. If an aggressive stabilization program has been implemented throughout the life of the project, this step may be fairly simple. Final stabilization consists of bringing an area to final grade and applying a permanent stabilization method to protect the area from the forces of erosion. Therefore, final stabilization does not have to occur at the end of a project. During the course of construction, areas at final grade can and should be permanently stabilized. Construction traffic should be excluded from areas that have been permanently stabilized. Some examples of areas conducive to final stabilization are privacy berms, basins, common areas, and drainage swales.

It is not always practical to apply vegetative cover or an alternative cover to protect the soil surface during construction and land-disturbing activities. Therefore, it is necessary to use runoff control and sediment trapping measures. These measures should be viewed as a second or third line of defense to manage storm water runoff and retain sediment. As land-disturbing activity increases in size and/or intensity, lower cost erosion control measures will be replaced with more expensive, less efficient, structural runoff control and sediment control measures such as diversions, dikes, and sediment basins. The utilization of larger structural measures will also require an increased level of design and cost more to construct and maintain.

All storm water management measures selected, designed, and constructed on a project site should be in accordance with the standards and specifications provided in Chapter 7 of this manual, similar guidance documents, or proven industry and engineering standards. Improper use or inadequate installation may result in failure of storm water quality measures, off-site discharge of pollutants, and increased costs required for the remediation of problems resulting from the failure.

Runoff Management – Construction

Effective management of construction activities and associated pollutants requires controlling and managing storm water runoff on the project site. Once storm water runoff begins to move across a project site, it will need to be managed so that it does not seek its own course and impact construction and land-disturbing activities. Several storm water measures have been developed to manage storm water runoff.

The primary purpose of storm water runoff management on a construction site is to control the volume of runoff, divert runoff to appropriate sediment control measures, and discharge runoff in a nonerosive manner. Runoff volume will be one of the determining factors in the selection of runoff management measures. Large drainage areas should be avoided when selecting runoff management measures because it is generally very difficult and costly to handle huge volumes of runoff at concentrated points. When selecting storm water management measures, a concerted effort should be made to balance or minimize the volume of runoff diverted to specific storm water quality measures.

Runoff management planning can be divided into distinct components: 1) runoff controls and 2) runoff conveyances and outlets.

1) Runoff Controls

Runoff control measures are designed to reduce the velocity of storm water runoff, carry concentrated runoff down slopes without causing erosion, and direct storm water runoff to stable outlets or sediment control measures. Depending on site conditions, some of these measures may also provide limited sediment trapping.

There are several types of runoff control measures that can be used to manage storm water runoff. The most commonly used measures are temporary and permanent diversions. Other runoff control measures include but are not limited to check dams, slope drains, and water bars.

The first principle for controlling storm water runoff is to minimize the length and steepness of slopes. As slope length and grade increases, so does the potential for erosion. One method of reducing the erosion potential in these situations is to break up the length of the slope. Reducing the length of the slope reduces the ability of storm water runoff to flow in an uncontrollable manner. Slope lengths can be shortened by stair-stepping (i.e., benching grades) or installing diversions across the slope. When installing benches on a slope, the cut should be tilted into the slope to allow runoff to be channeled along the inner edge of the bench. Runoff should always be routed to a stable outlet. If the runoff is sediment-laden, it should be directed to a sediment treatment device such as a sediment basin, sediment trap or other appropriate measure.

The second principle of runoff control is to reduce the velocity of storm water runoff. There are several storm water measures and principles that can be used to reduce runoff velocities. Some of these include reducing slope lengths, maintaining existing vegetative cover, preserving vegetated buffer strips around the lower perimeter of the land disturbance, and installing controls, such as check dams and diversions.

The third principle of runoff control is to divert storm water runoff away from active construction zones and other critical areas. This principle can be used to segregate storm water runoff and divert it to either several stable discharge points or to a single point of discharge.

Diversion of storm water runoff can have a major impact on the selection of sediment control measures. The ability to control the direction and volume of runoff to designated points in the landscape allows for greater flexibility in the selection and design of sediment control measures. For example, redirecting runoff to a single discharge point will generally require larger, more expensive sediment control measures and outlet structures, whereas directing the runoff to several discharge points will allow for the use of smaller, more manageable sediment control measures.

In situations where the diverted storm water runoff comes in contact with exposed soil the runoff should always be conveyed to an appropriate sediment control measure.

Storm water runoff associated with a construction site generally includes off-site runoff as well as on-site runoff. One of the major rules or principles of plan development is to design a runoff management system that only treats sediment-laden runoff. To accomplish this objective, it is necessary to segregate off-site runoff from storm water runoff associated with active construction areas. For example, a perimeter dike or diversion can be used to intercept runoff from an area up slope of an active construction zone and divert it around the construction zone. A critical element in implementing this principle is stabilization of the diversion berm and/or conveyance channel. If the flow channel is not adequately stabilized, flows should be directed to appropriate sediment control measures. Diversions can also be used on the down-slope side of construction zones to direct runoff to an appropriate sediment control measure such as a sediment basin.

As noted in earlier discussion, subdividing larger drainage areas into smaller drainage areas allows for the use of smaller, less expensive sediment control measures. This is also true of runoff control measures. A smaller drainage area may allow the use of a sediment trap verses a larger drainage area which might require use of a sediment basin.

2) Runoff Conveyances and Outlets

The principle behind runoff conveyance management is to move storm water across a project site without causing erosion. Open channels, drainage swales, and drainage pipes/conduits are examples of runoff conveyance systems. Conveyance systems and outlets should be designed to accommodate the runoff capacity and velocity that will be associated with the construction and post-construction land use.

Conveyance systems should be designed with gentle grades to keep flow velocities low. Flow from the conveyance system should be discharged in a manner that does not cause erosion. This is usually accomplished through the use of outlet protection and grade stabilization structures.

Runoff conveyance systems should be constructed and stabilized prior to becoming functional. Every effort should be made to prevent sediment from entering the conveyance system, especially after it becomes functional.

Runoff conveyed through channels and swales will naturally erode the channel bottom and side slopes if they are not stabilized. Therefore, runoff conveyance systems should be stabilized immediately after construction. Attempting to stabilize channels with straw crimped into the soil is usually ineffective. More substantial erosion control measures such as appropriately applied erosion control blankets and/or turf reinforcement mats are more effective at protecting the soil surface until such time as vegetation becomes well established.

Erosion control blankets are composed of mulch that is sewn or intertwined in a netting material. Mulch materials range from straw, wood and coconut fiber to synthetic fibers. Each has its limitations. However, for higher velocity flows a heavier or special blanket may be required to stabilize the conveyance channel.

Turf reinforcement mats are designed to reinforce vegetation by allowing the root system of the plant to become entwined in the synthetic matrix. These systems are suitable for higher flow velocities than standard erosion control blankets. Another method for stabilizing channels is to line them with a hard armament such as rock.

Both grass-lined and rock-lined channels will help slow flow velocities. Grass-lined channels have an advantage over rock-lined channels in that they are aesthetically pleasing, easily maintained, and provide a minimum level of pollutant removal from storm water runoff associated with the post-construction land use.

In some situations it is necessary to provide a grade transition to maintain low channel gradients within the conveyance system or to provide a stable outlet at the discharge of the conveyance system or a pipe outlet. To preserve the integrity of the receiving channel or water body, it is also important that conveyance systems discharge to a stable outlet which has been designed to accommodate peak runoff volumes and velocities from the conveyance system. In addition to accommodating peak flow volumes and discharge velocities, outlet protection measures should be designed to provide energy dissipation and prevent scouring at the point of discharge. Measures such as riprap aprons and grade stabilization structures are typically used to dissipate energy of the channel flow and pipe discharge points.

Sediment Control – Construction

Once soil is detached, the soil material becomes suspended in storm water runoff and flows to down-slope positions in the landscape. Soil material that is suspended in runoff is defined as sediment. If left untreated, sediment-laden storm water will discharge from the active construction area and eventually deposit its sediment load in creeks, rivers, wetlands, and other environmentally sensitive areas.

It is not practical to assume that all erosion and sedimentation issues associated with a construction project can be controlled through surface stabilization. Construction, by nature, involves land disturbance and as such will result in soil material being left unprotected as clearing and grading operations occur. Therefore, sediment control must be an integral part of any erosion and sediment control plan.

Sediment controls are typically more difficult to implement, more costly to install and maintain, and less effective than surface stabilization controls. Sediment control measures should be selected as secondary and tertiary treatment measures. They should be implemented on a construction site with the objective of eliminating or, at a minimum, reducing the discharge of sediment-laden storm water runoff to off-site areas, unique resources, and waters of the state.

There are several types of sediment control measures. Types of sediment control measures include but are not limited to sediment basins and traps, sediment barriers and filters, and inlet protection.

Several factors should be considered when evaluating the placement of sediment control measures. Sediment control measures are typically located below active construction areas, below areas that are void of protective cover, and above environmentally sensitive or unique areas such as creeks, streams, lakes, ponds, public streets, and wetlands. They should be located in relatively level areas or in natural depressions. Sediment control measures should not be placed in areas where their construction would result in excessive land disturbance or where it would be difficult to maintain them. It is important to remember that poorly located sediment control measures often create construction site management problems and that they can cause additional erosion and sedimentation problems.

Sediment control measures are typically used around the perimeter of active construction zones to detain sediment-laden runoff and allow for trapping or settling of the sediment. To accomplish these objectives, the control measures must be in place and stable before initiating land clearing and grading activities. While perimeter sediment controls are important, it is also important to remember that there are several other measures that can be used on the project site. A concerted effort should be made to develop a comprehensive plan that includes a complete erosion and sediment control system. A complete erosion and sediment control system will consist of several measures working in concert to treat storm water runoff before it is discharged from the project site.

Sediment control measures can be either temporary or permanent. They typically function by filtering storm water runoff or impounding runoff for an adequate length of time to allow suspended soil particles to settle out. The pollutant removal efficiency of sediment control measures varies greatly. The pollutant removal efficiency of some measures can be as high as 50 percent. Pollutant removal efficiency rates are dependent on many factors including the design of the sediment control measure and the measure's storm water retention time.

Drainage area size must be considered when selecting sediment control measures. For example, most storm drain inlet measures have limitations of one-quarter to one acre maximum drainage area.

In general, the most efficient sediment control measures are sediment basins and traps. Proper sizing of sediment basins and traps is critical to effective sediment control. This manual provides criteria, standards and specifications that can be used by engineers in the design of these measures. Whenever feasible, larger drainage areas should be divided into subwatersheds with each having their own sediment basin. It is best to locate sediment basins in parallel rather than in series. Placing basins in parallel eliminates the possibility of a domino effect if one basin fails. Damage from basin failure will also be substantially less if a small basin fails versus a large basin.

Maximum drainage area limitations have been established for many of the sediment control measures contained in this manual. In some instances, these maximum limits can be exceeded if the measure is designed using approved engineering principles and additional design parameters are taken into consideration.

Site designers are often faced with a situation where a creek or river flows through a project site. The placement of sediment control measures in these conveyances should be avoided. By placing controls within natural conveyance systems, additional watershed acreage is being treated unnecessarily. It is generally best to let these features flow through the site. It is also not logical to trap sediment within a system that the storm water pollution prevention plan is designed to protect in the first place. In fact, locating sediment control measures in these situations generally requires permits from local, state, and federal regulatory authorities. In most situations, it will be almost impossible to obtain approval for the placement of storm water management measures in a natural channel.

Finalizing the Erosion & Sediment Control Plan

After drainage areas have been determined, site features evaluated, and appropriate measures selected for the situation, the measures should be incorporated into the erosion and sediment control plan. Locations of the measures should be identified in the plans and design standards and specifications included as part of the plan’s construction details. Standards and specifications, design parameters, maintenance requirements, and detailed drawings for erosion and sediment control measures can be found in Chapter 7 of this manual.

Post-Construction Pollution Prevention Plan

The alteration of land can significantly change the dynamics of a watershed. The net impact is dependent on the magnitude of the change to the landscape. Many construction projects are directly related to residential, commercial, highway, and industrial development. Each of these different types of development can have significant impacts on Indiana’s soil and water resources.

The primary purpose of post-construction storm water pollution prevention plans is to minimize the discharge of pollutants associated with the final land use of the project. Plans should include storm water quality measures that are specifically targeted to address pollutants that will be generated at the site. The plan should also outline specific operational procedures that will reduce the generation and introduction of pollutants to storm water runoff. In addition to water quality, post-construction storm water pollution prevention plans often incorporate storm water management measures designed to address an increase in runoff volumes.

The recommended approach in developing a post-construction storm water pollution prevention plan is to use a variety of design principles and storm water quality measures to achieve the overall objective of pollution prevention.

Post-Construction Assessment of Pollutants & Impacts of Development – Project Specific

Before selecting a storm water quality measure it is important to assess the potential pollutants that will be associated with the final land use. Evaluating and understanding the pollutants that will be associated with the project is a critical step in developing a post-construction storm water pollution prevention plan. Evaluation of potential pollutants should be done in the early stages of the planning process. Knowledge of the pollutants that are associated with the final land use of a project allows for advanced planning and the selection of cost-effective storm water quality measures.

The first step in assessing pollutants is to identify the land surfaces that are planned for the project. Examples of surfaces that will generate storm water runoff include building rooftops, pavement, and grassed areas. Once land surfaces have been identified, the next step is to determine the types of activities that will occur on these surfaces and the potential pollutants that will be generated. Some common activities include but are not limited to parked vehicles, storage of processed or manufactured products, service stations, road maintenance, and landscape maintenance (e.g., mowing, fertilizer and pesticide applications, etc.). Chapters 1 and 8 of this manual provide an in-depth discussion of specific land uses and the pollutants associated with each type of use. After the site designer has identified the types of land surfaces and types of activities that will occur on these surfaces, he or she can begin to assemble a list of potential pollutants that must be considered in the development of the post-construction storm water pollution prevention plan.

Water quality impacts can also be affected as a result of increased runoff volumes. Increased runoff volumes and discharge rates, as a result of an increase in impervious surfaces, can directly affect downstream areas. Receiving creeks and streams do not necessarily have the capacity to accommodate and transport the increase in runoff. The overall impact includes changes in the dynamics of the channel, including bank erosion, down cutting of the channel bottom, and increased flooding. It is important that runoff is released in a controlled manner that will not impact associated watersheds.

Performance Standards

Storm water management measures often have multiple objectives, including water quality protection and water quantity control. While this manual predominately focuses on storm water quality, quantity is also a resource concern. Once the pollutants associated with a project have been identified and an assessment of the storm water runoff has been completed, the site designer can begin developing a post-construction storm water pollution prevention plan. When developing the plan, it is important that site designers have access to performance standards for the selected storm water management measures.

Currently, the state does not include these standards in storm water regulations. However, local governmental entities may have their own regulations and it is the responsibility of the plan designer to investigate these requirements. As a guideline for plan preparation, this manual uses the following standards.

- The basic goal for development is to assure that post-development peak discharge rates and discharge volumes do not exceed the predevelopment levels.

- Storm water quality measures selected should be designed to treat at least one-half inch of storm water runoff (water quality volume or storage), at a minimum, from the impervious surfaces. Treatment goals should be targeted to remove at least 80 percent of the total suspended solids from runoff on an annual average basis before it is discharged into waters of the state or to adjacent properties.

There are numerous storm water management measures and operational activities that can be used to treat storm water runoff and reduce the discharge of pollutants. Each measure alone may not be able to achieve the desired pollutant removal rate of 80 percent. Achieving the 80 percent removal rate may require the use of a variety of measures designed to work in concert with one another. The performance standard of 80 percent targets the removal of total suspended solids and pollutants that attach to those particles. This performance standard does not address the removal of pollutants that remain in solution or that may attach to finer particle matter. To remove these pollutants may require additional measures. This may be particularly important in areas of high pollutant loading (i.e., hotspots), such as gas stations and fueling facilities, to further target the removal of lead, copper, or zinc, in addition to polyaromatic hydrocarbons.

Post-construction treatment systems typically consist of a series of storm water management measures designed to work in concert with one another for the purpose of removing pollutants from storm water runoff. These systems are often referred to as a "treatment train." Natural site features, site design planning principles (see Chapter 4), and storm water quality measures specifically selected to address the targeted pollutants are the three major factors to consider when designing a treatment train. When all three of these design elements are incorporated into the final plan there will be numerous opportunities to improve water quality, create wildlife habitat and corridors, preserve and create greenways/open space, and protect downstream waters.

A typical treatment train may include a combination of grassed swales, infiltration basins, and the use of a wetland treatment cell. The effectiveness of hydrodynamic separators may also be increased and target other pollutants by providing secondary treatment through the installation of an in-line filtration system. By combining several measures rather than selecting one measure for the treatment of storm water the level of reliability of pollutant removal can be improved. The effective life of a measure can also be increased by combining it with a pretreatment device such as a vegetated buffer strip or grass swale designed to remove total suspended solids from the storm water runoff before it enters a downstream treatment measure.

Storm water measures that are installed as part of a treatment train are usually installed with the least expensive and most easily maintained measure being placed at the highest point in the system. A prime example is the initial treatment of building runoff. The runoff can initially be directed through grassed swales and eventually discharge into other treatment measures.

One example where a treatment train might be used is a large parking facility. These areas are typically associated with a large volume of trash and debris that is carelessly disposed of on the parking area. If a wetland cell were to be installed to treat runoff from this facility, the wetland cell would rapidly fill with paper products, cans, and other trash. It would be difficult to remove trash from the wetland cell and over time, the wetland would become unsightly. In this situation, it would be best to remove the trash through pretreatment before the runoff is discharged to the wetland.

Selection of Storm Water Management Measures – Post-Construction

Post-construction storm water management measures are selected, implemented, and constructed to minimize the discharge of pollutants and the impact storm water runoff will have on downstream areas. The selection of storm water quality measures will be decided based on the professional judgment and preference of the site designer.

During project layout and design the site designer makes many decisions in regard to the location of storm sewers, streets, and other infrastructure that may have a direct impact on the natural resources of the project site. At this stage of the planning and design process, the site designer should evaluate and consider several of the alternative design concepts and principles listed in Chapter 4 of this manual. These concepts and principles can be used to protect and preserve unique, critical, and environmentally sensitive areas and reduce the amount of impervious surface area associated with the project. Incorporation of these design principles and concepts into the project design and layout can have a significant impact on final land use cover and the amount of pollutants generated from these areas. Using these site design concepts and principles, it is often easier to modify the site design and layout of the project to reduce the amount of pollutants generated than to rely solely on structural storm water treatment measures for pollutant removal. The end result will be improved efficiency and lower maintenance costs of the storm water management system.

At this stage of plan development, all planned conveyance systems and impervious surfaces have been identified by the site designer. The next step is to evaluate the watershed associated with each land use. During this phase of assessment it is important to consider the storm water drainage system (e.g., swales, storm sewers, etc.) as well as overland flow of storm water runoff for the project. At this point, the process of evaluating specific discharge points within the watershed can begin. This process will help identify whether or not any land uses that generate specific pollutants are isolated. If specific pollutants are isolated within a drainage system, the storm water quality measure or measures applied to the situation should be targeted to those pollutants. In addition to pollutants associated with the watershed, selection of storm water management measures should take into consideration post-construction runoff volumes and storm water runoff velocities.

Once a list of potential pollutants is generated, a thorough evaluation of the project must be conducted. The site designer should re-evaluate the project layout and design and determine if modifications can be made to the project to eliminate or significantly reduce pollutant generation or discharge. After all final decisions and modifications related to site design and layout have been made, it will be necessary to re-evaluate the list of potential pollutants and select the appropriate storm water quality measures to minimize their discharge.

Storm water quality measures should be selected based on the pollutants associated with the land use. Site designers should be cognizant of the fact that additional measures may be required to effectively control storm water discharge rates. To ensure that each storm water measure functions effectively and efficiently, measures must be applied to the correct field conditions, designed according to site conditions, installed correctly and at the appropriate time, and properly monitored and maintained.

Post-Construction Site Management Goals

In addition to project site design considerations, pollutants can be reduced through project management, operational procedures, and program implementation. These measures are often referred to as source controls. Source controls focus on activities that limit the generation of pollutants at the source rather than the treatment of runoff. Source controls include day-to-day activities that include but are not limited to trash recycling/disposal, washing equipment and vehicles, and periodic street sweeping.

Land use planning can be an effective tool in addressing storm water issues. Local planning decisions can have a great influence on the balance between growth and development needs and the resource issues within a community. This can be achieved through the establishment of local ordinances that incorporate creative approaches to land development. Chapter 4 of this manual provides information on common resource issues and alternatives for creative site planning and design. Other local initiatives include watershed protection plans, protection of critical resource areas, and implementation of master plans that allow for development while minimizing the effects of urbanization.

Important, unique, and environmentally sensitive resource areas can be protected or preserved by implementing programs or ordinances that require buffer zones, easements, and setbacks. Several communities in Indiana have enacted ordinances for the protection of wetlands and karst features to protect local natural resources.

Private citizens can play a role by collecting and properly disposing of pet waste, reducing and/or properly applying fertilizers and pesticides, participating in neighborhood recycling programs, and properly disposing of household chemicals and wastes.

Education is another method that can be used to achieve pollution prevention. Education and public outreach efforts should be used to educate both youth and adults. Educational programs should focus on creating an understanding of how everyday activities contribute to storm water pollution. Education and public outreach can be achieved through public meetings, school programs, adoption of highways and waterbodies, storm drain marking, and other similar programs.

Source controls are discussed in more detail in Chapter 9 of this manual. Source controls should not be substituted for the implementation of effective permanent storm water quality measures.

Storm Water Management and Flood Control

A change in land use can significantly increase runoff and have a detrimental impact on receiving water. It is important that the plan designer reduce the impact of additional runoff and the rate at which the runoff is released.

One of the primary goals of storm water management is to mimic the way runoff left the site before development. Land development creates impervious surfaces which result in less infiltration. Less infiltration results in a greater volume of runoff. The additional runoff, together with an improved and more efficient conveyance system, results in an increase in runoff rates. Land that is developed will typically change in its overall characteristics and result in the generation of a new set of pollutants based on land use. The runoff will tend to contain more pollutants and be discharged from the site at a greater rate and volume. One of the challenges is to develop land in a manner where post-construction discharges resemble predevelopment discharges.

Historically, Indiana communities have addressed storm water issues with relation to flooding. Many communities across Indiana have established ordinances that require detention and retention standards by establishing peak discharge limits. Typically, these standards do not address pollutants that are associated with the land use. These standards indirectly reduce pollutant loading by releasing storm water at rates that do not cause bank erosion and scouring in the receiving body of water.

Several multipurpose storm water management measures can be used in conjunction with flood control measures. These measures include infiltration systems, wetland cells, pretreatment measures, and modification of detention/ retention structures that have been designed to enhance the removal of storm water pollutants.

Pollution Treatment

The post-construction storm water measures listed in this manual are designed to remove storm water pollutants through several different methods or processes (e.g., filtration and infiltration). For simplicity the measures have been grouped or categorized based on primary pollutant removal processes and similar design characteristics. The four major categories are 1) filtration systems, 2) infiltration systems, 3) settling and flocculation measures, and 4) proprietary measures. Below is a brief discussion of each category. Specific information on the individual measures is contained in Chapter 8 of this manual.

1) Filtration Systems

Storm water filtration systems operate on the principal that runoff is intercepted and allowed to pass through a filtering medium such as vegetation, sand, or organic material for pollutant removal. There are two basic types of filtration systems: 1) surface filtration and 2) underground treatment. Surface filtration systems include measures such as compost filters, filter strips, vegetated swales, and riparian buffer zones. Underground systems include measures such as sand filters and peat filters.

Filtration systems are primarily designed to remove pollutants. They are not intended for use as storm water retention measures. Filtration systems are typically used to treat runoff from small residential, commercial, and industrial sites and parking lots.

Surface flow filtration systems are typically designed to intercept sheet flow runoff and allow the runoff to pass through the filtering medium. Grass filters and compost mulch berms are two of the most common filtering mediums. Riparian buffer zone systems are also an effective filtration system because part of the riparian zone includes a grass filter as part of the overall system. In addition to conveying storm water runoff, vegetated swales can provide some filtering of storm water runoff, especially during low flows. Surface flow filtration systems are similar to those used during the construction phase of a project.

Underground filtration systems are used to treat runoff below the surface. These systems are often used in areas with limited space because they can be placed under parking lots and other areas within a project site. Underground filtration systems are typically designed to provide for different levels of pollutant removal. After runoff is filtered it can either be returned to the conveyance system or collected by an underdrain and allowed to percolate into the underlying soil material or infiltration medium (refer to the following infiltration measures).

2) Infiltration Systems

Storm water infiltration systems are designed and work on the principle of collecting storm water runoff and then slowly releasing the stored runoff, via percolation, into the underlying soil or contain it in an underground detention reservoir, where it may or may not be treated, before it is allowed to infiltrate into the underlying soil or discharge through a pipe connected to the storm water conveyance system or a secondary treatment system. Storm water infiltration systems generally reduce storm water runoff volumes and the associated suspended solids and pollutants attached to those solids. The level of pollutant removal effectiveness is highly dependent on the permeability of the underlying soil material. Highly permeable soils are relatively ineffective at removing many types of pollutants from runoff, especially if the pollutants are soluble or easily dissolved in the runoff. Soils with a low permeability rate may not provide sufficient residency time between storm events or the soil interface may seal over, which severely limits pollutant removal. Therefore, infiltration measures may require some form of storm water runoff pretreatment before runoff is allowed to enter the infiltration bed, or the infiltration bed may require modification to ensure appropriate permeability rates for the targeted pollutants.

Storm water infiltration measures should be carefully sited and designed to minimize the risk of ground water contamination. When considering the use of storm water infiltration measures, land use and potential pollutants generated within the drainage area of the infiltration measure should be carefully evaluated, especially in areas that are designated wellhead protection areas. Pretreatment systems that target specific pollutants and are designed to high removal standards may alleviate these concerns.

Infiltration measures are usually best suited for treating storm water runoff from small drainage areas. In general, these systems should not be used in areas where the land use of the contributing drainage area is associated with high traffic volumes, industrial and manufacturing facilities, chemical storage, high levels of pesticides, the washing and maintenance of vehicles or equipment, or where wastes are handled. In addition, infiltration measures should not be used in areas with high sediment loads or during construction, especially in situations where sediment-laden runoff from disturbed areas will be directed into the system.

Project site owners may be required to obtain special permits in situations where infiltration systems have the potential to be a conduit to ground water supplies. Permits may be required through the U.S. Environmental Protection Agency, the Indiana Department of Environmental Management, or local units of government. For example, storm water management systems that may have an effect on ground water supplies may be required to comply with the U.S. Environmental Protection Agency's Class V Injection Well Section of the Underground Injection Control Program.

By definition, a Class V injection well is any bored, drilled, or driven shaft, or dug hole that is deeper than its widest surface dimension, an improved sinkhole, or a subsurface fluid distribution system. Improved sinkholes are natural karst depressions or open fractures that have been intentionally modified or designed for storm water management. A subsurface fluid distribution system is defined by the U.S. Environmental Protection Agency as an assemblage of perforated pipes, drain tiles, or other similar mechanisms intended to distribute fluids below the surface of the ground.

The U.S. EPA administers Indiana's Underground Injection Control Program. For more information regarding Class V injection wells, the plan designer should refer to the U.S. EPA, Region V guidance requirements.

Infiltration measures are prone to sealing or plugging. Therefore, it is often necessary to provide pretreatment of storm water runoff to remove pollutants such as oil, grease, solids and other floatables that would affect the integrity of the infiltration measure. It is equally important to provide pretreatment of storm water runoff if the underlying soil material is highly permeable and there is a high potential for pollutants to percolate or infiltrate into the underlying soil or filtering medium and adversely affect ground water quality.

Secondary treatment should be considered when soil permeability rates are too slow and there is a potential for pollutants to bypass the system, or when a closed underground storage system is used. Closed underground systems are designed to collect surface runoff through percolation or as direct flow into an enclosed, impermeable underground reservoir or chamber. Water collected in the closed system is usually routed to a conveyance system. The storm water discharging to the conveyance system may require secondary treatment to remove pollutants associated with the inherent land use.

Pretreatment and secondary treatment systems can be used in tandem to effectively treat storm water runoff.

Infiltration measures include but are not limited to porous pavement, porous pavers, infiltration trenches, infiltration chambers, infiltration ponds, and bioretention.

Porous pavers and porous pavement are two types of infiltration systems that are an alternative to conventional paving methods. These systems are designed to allow rainwater to pass through the system and discharge or percolate into an underlying filter medium. These types of systems reduce runoff, promote ground water recharge, and provide limited pollutant removal. Porous paver systems typically include grass grid pavers (e.g., plastic or concrete) and paving blocks. Porous pavement includes both pervious concrete and porous asphalt. Use of these systems are typically applicable to low-traffic areas including but not limited to overflow parking, residential driveways, light commercial use, commercial fire and emergency access lanes, and sidewalks. Decisions to use these systems can be identified early in the planning process and later factored into final design and the selection of storm water quality measures.

Infiltration trenches and infiltration basins are measures designed to reduce runoff volume, remove suspended solids and pollutants attached to the solids, and promote ground water recharge by allowing storm water runoff to infiltrate into the ground. Infiltration trench systems consist of shallow excavated trenches filled with a suitable medium to promote infiltration. The use of these systems is typically limited to smaller drainage areas. Conversely, infiltration basins, even though they function similarly to an infiltration trench, are impoundments designed to retain storm water runoff above ground over a short period of time and allow it to infiltrate into the soil. Filtration basins are more suitable for use on larger drainage areas.

Bioretention systems are shallow, depressional areas designed to manage and treat storm water runoff. They typically include a soil filtering medium and selected plants. Pollutants are removed through plant uptake and deposition when pollutants bond with soil particles as the runoff flows through the vegetation. Runoff collected in the bioretention system is allowed to either percolate through the soil, providing additional treatment and pollutant removal, or it may be collected by an underdrain and discharged to the storm conveyance system.

3) Settling and Flocculation Measures

Settling and flocculation measures are typically storm water management measures that have been modified to allow for the settling or flocculation of suspended solids and pollutants that may be attached to the solids. Measures in this category include but are not limited to dry ponds, wet ponds, storm water wetlands, and subsurface detention structures. The following discussion provides a brief overview of some of these measures and some of their limitations.

Dry detention basins are usually designed to temporarily hold storm water runoff and release it gradually. They help to reduce peak discharges to the receiving channel and are usually designed to completely dewater within a short time frame, typically 24 hours or less. Because of the short retention time, this type of basin does not address the issues of reducing storm water runoff volumes or pollutant removal. They are limited in their ability to retain suspended solids as subsequent storm events may resuspend trapped solids. By releasing water at a controlled rate, dry detention basins can provide water quantity control and protection of downstream areas. Dry detention basins can be useful as part of a treatment train that includes other measures designed to remove pollutants from storm water runoff.

Extended dry detention ponds are modified dry detention basins. They are designed to provide some measure of water quality enhancement by incorporating forebay ponds and/or isolated extended detention storage cells in the design of the pond. These appendages allow for the storage of additional storm water runoff and extend retention times to allow for the settling of solids.

Wet ponds provide pollutant removal as well as attenuation of peak flows and channel protection. Wet ponds are storm water ponds that provide for removal of pollutants by allowing solids to settle to the bottom of the pond. These systems are designed to remove suspended solids and pollutants attached to the suspended solids. Wet ponds can provide some removal of soluble pollutants through the biological processes of aquatic and pond fringe vegetation. Increased pollutant removal can also be achieved through basin design variations such as the addition of forebay ponds and multiple cells (e.g., wet pools, wetlands). These cells should be aligned in series to increase overall pollutant removal.

Storm water wetlands are man-made systems that incorporate a variety of plant material and are designed to increase retention time of runoff by increasing the travel time for storm water to flow through the system. Runoff entering the wetland system is designed to remove pollutants through deposition of solids and plant uptake.

Underground detention systems are storm water management systems designed to provide below grade storm water retention, thus freeing the land surface for development. This type of storm water management measure can be very useful in situations where land is not available for an alternative storm water quality measure. Underground detention systems do not reduce storm water runoff volumes due to their relatively quick dewatering times, but they are an appropriate measure for controlling storm water quantities. They can be used to control peak flows, reduce downstream flooding, and provide downstream channel protection. Underground detention systems are of little benefit for improving water quality. They do allow for settlement of coarse, suspended solids, but the solids will usually become resuspended during subsequent rain events. Therefore, underground detention systems should be used as part of a treatment train that uses other storm water measures as pretreatment and secondary treatment devices for the removal of pollutants, reduction of runoff volumes, and ground water recharge.

4) Proprietary Measures

Proprietary measures are manufactured systems designed to treat storm water runoff. There are a variety of proprietary systems available commercially. The systems consist of a wide variety of technologies designed to remove pollutants from storm water runoff. Manufacturers will typically provide data on pollutant removal and removal efficiency. Many manufacturers provide independent testing as testimony to the performance of their product.

Catch basin inserts are proprietary devices that treat runoff entering a catch basin. There are a variety of catch basin inserts available commercially. They typically contain a filtering medium such as sand, carbon, or geotextile. Sediment is the primary pollutant targeted, however selection of an appropriate filtering medium can provide for removal of oils and metals. These systems have limited capacity, short retention time, and require frequent cleaning or replacement to maintain efficiency. They are susceptible to clogging and may result in flooding when not properly maintained. These systems are limited in use due to low efficiency and are best used as part of a treatment train that incorporates other storm water management measures.

Hydrodynamic separators consist of a series of treatment chambers that operate on a principle known as swirl concentration. These systems are modifications of the traditional oil/grit separator. Hydrodynamic separators commonly rely on vortex-enhanced design to remove sediments from runoff. They will typically remove suspended solids, oil, and floatables. Swirl concentration is the most common technology used in hydrodynamic separators. Other systems use combinations of screens, baffles, and inlet and outlet structures to remove debris, suspended solids, and oil. There are many different types of hydrodynamic separators available commercially; each has its own variation of technology.

Hydrodynamic separators are well suited for use in areas where there is a need for removal of pollutants and high sediment loads over a wide range of flow conditions. These devices can be used to treat runoff from relatively small areas with high traffic volumes or areas that have a high potential for spills such as parking lots, streets, loading docks, service stations, refueling areas, automotive repair facilities, fleet maintenance areas, commercial vehicle washing, and industrial facilities that have a high potential for accumulation of fuels, oils, grease, and other pollutants associated with mechanical equipment. Hydrodynamic separators alone may not remove 80 percent of the pollutants often associated with gas stations or other storm water hotspots. A secondary in-line filter may be required to achieve the overall objective.

When used in conjunction with storm water detention facilities, hydrodynamic separators should be placed upstream of the detention facility to provide runoff pretreatment and help prevent the loss of detention volume, especially when underground facilities are used.

Hydrodynamic separators can be used as a primary storm water runoff treatment device or as a pretreatment system for other storm water quality measures. Hydrodynamic separators are also an excellent retrofit option when upgrading storm sewer systems in highly urbanized areas where more conventional or aboveground treatment is not practical due to space limitations.

Inspection & Maintenance

All post-construction storm water quality measures require periodic inspection and maintenance to ensure they are functioning according to design standards. The operation and maintenance provisions for each storm water management measure should be outlined in the storm water pollution prevention plan. The plan should include inspection frequency, maintenance requirements, and identification of the person or entity responsible for operation, inspection and maintenance of the storm water management system.

Long-term maintenance is a key factor in the evaluation, selection, and design of post-construction storm water management measures. The selection, siting, and design of measures should provide easy access for the entity that will be responsible for inspection and maintenance of the measures. All storm water quality measures must be maintained to remain operational and functional. The level of maintenance will vary with each measure. Some measures are more easily maintained than others. For example, swales only require periodic fertilization and mowing. Other measures will require intensive maintenance. Structural measures typically have higher, more intense maintenance requirements. These measures include but are not limited to hydrodynamic separators, infiltration systems, and filters. Some measures may only require hand tools or small landscape equipment. Other measures will require use of heavy or specialized equipment. When larger equipment is required for maintenance, the site designer should provide maintenance roads or access lanes that can be used for easy access to the measure.

The final consideration in maintenance of post-construction management measures is ownership and who will have long-term responsibility for operation, inspection, and maintenance of the measures. This issue is vital to ensuring that the measures will remain functional. Project site owners should continue to maintain the storm water management system until such time as the system is transferred to the person or entity that will assume long-term responsibility for operation, inspection, and maintenance.

Following the completion of construction, responsibility for storm sewer systems, including post-construction measures, are often transferred to local governmental entities. Systems that are owned or operated by a municipality or public utility are typically not a major concern for long-term maintenance. Local government and public entities can ensure long-term maintenance and monitoring through fees, taxes, or other funding sources. Typically, this approach is taken with residential developments.

It is generally not prudent to transfer operation and maintenance responsibilities to a homeowners association. The long-term maintenance and functionality of measures is critical to their operation. Failure of these systems can result in flooding, harbor vectors, or cause a nuisance. Homeowners associations are not necessarily solvent and at some point may cease to function. Permanent storm water management measures should also not be located on individual residential lots. The responsibility to maintain these measures may be costly and homeowners usually do not understand the consequences associated with failure to maintain the system. Local governmental entities usually maintain regulatory responsibility for the functionality of the measures. In these situations, the local governmental entity would be responsible to ensure that a homeowner or homeowners association is maintaining the measure. Failure of the homeowner or an association to maintain the measure may require the local governmental entity to take enforcement action against individuals within the community.

Storm water management systems that are associated with multi-family residential developments, commercial developments, and industrial developments or multi-lot parcels will typically be maintained by the facility/property owner. In these situations, the local governmental entity may require agreements or permits to ensure long-term operation and maintenance of the storm water management system.

The maintenance requirements described above should always be incorporated into the storm water pollution prevention plan. Details for maintenance should always be discussed early in the development process and final decisions on long-term maintenance agreed to before finalizing the measures that will be used to manage and treat storm water on the project site.

Modifying Existing Storm Water Management Systems

It is relatively easy to incorporate storm water quality and quantity management measures into new development projects. This is especially true when the plan designer considers post-construction land use issues early in the planning process. However, there are situations where a storm water system will require modification to address either a water quality or quantity issue. Modification of an existing storm water management system is often referred to as a retrofit.

Retrofits are applicable to situations in existing and redevelopment areas that are highly urbanized. Retrofits can apply to existing drainage systems, storm water management structures, outfalls, road culverts, highway right-of-ways, and parking lots to name a few. One of the purposes of retrofitting an existing system is to correct problems associated with older and poorly designed or maintained storm water management systems. The objective of a retrofit project may be to reduce pollutant loadings, address runoff quantities, address nuisance issues, or resolve maintenance issues.

Retrofits are a viable option for enhancing existing storm water management systems when the current land use or space limitations prohibit the use of other types of storm water management measures. Accessibility for maintenance may also be a limiting factor.

Incorporating storm water retrofits into existing or redevelopment projects can reduce the adverse impacts associated with storm water runoff. This manual describes many methods to reduce the impact of storm water runoff including the reduction of impervious surfaces and the installation of storm water management measures that specifically target pollutant reduction and removal and management of storm water runoff quantities. Site conditions may prohibit or eliminate the use of several of the measures listed in Chapter 8 of this manual. Storm water management measures used to retrofit a drainage system in existing or redevelopment areas may be less effective at pollutant removal versus their pollutant removal rate in new developments.

Modification of storm water management systems can be achieved through careful planning and design. If a measure cannot be completely adapted to a field situation, it may be possible to incorporate some of the site design principles, contained in Chapter 4 of this manual, into the existing storm water management system to accommodate treatment of storm water runoff. Where possible system retrofits should be used in conjunction with other storm water management measures to increase the overall effectiveness of the system.

DEVELOPMENT OF A CONSTRUCTION SEQUENCE SCHEDULE

A construction sequence schedule is a predetermined chronological listing of erosion protection, sedimentation control, and storm water management measures that are scheduled to be deployed in a timely manner with various land-disturbing phases of a construction project.

The purpose of a construction sequence schedule is to minimize the duration and amount of soil exposed to erosion by wind, rain, storm water runoff, and vehicle tracking and to provide adequate treatment measures to minimize the introduction of pollutants to storm water runoff.

A construction sequence schedule should be developed for and implemented on every construction project involving clearing, grading, and/or filling of the land surface. Implementation of a construction sequence schedule is especially important during periods of intense or prolonged rainfall.

Developing a construction sequence schedule for a project helps to establish a timetable for installing erosion and sediment control measures and post-construction storm water management measures and shows their likely compatibility with the project's general construction schedule. Appropriate sequencing of construction activities can be an efficient and cost-effective way to help accomplish these goals. Often, a proper construction sequence schedule can eliminate the use of more costly, yet less effective storm water measures.

A properly developed and implemented construction sequence schedule will provide for timely installation of storm water management measures that will protect the construction site from erosion and off-site sedimentation, regardless of the stage of construction or time of year. For a construction sequence schedule to be effective, it must clearly communicate to contractors, plan review authorities, and inspecting authorities what control measures are needed, where they are to be installed, and when installation is to occur. The schedule can be written in very general terms or it can be very specific and detailed. In the latter case, the construction sequence schedule might specify when each individual erosion and sediment control measure or device is to be installed (e.g., when each individual sediment trap or basin is to be installed or when each individual storm drain inlet protection device is to be installed) as land-disturbing activities progress across the project site. In either case, the schedule needs to be site specific.

Construction sequence schedules must be flexible. Project representatives and contractors must be given the opportunity to use construction techniques that are not scheduled, but because of timeliness, can greatly reduce erosion potential at the project site (i.e., reshaping earthen fills periodically to prevent overflows or construction of temporary diversions ahead of anticipated storm events). It is impossible to incorporate activities such as those listed above into a construction sequence schedule but they should be used whenever possible.

Construction sequence schedules should be followed as closely as possible throughout development of the project. Project representatives should monitor the weather forecast on a regular basis. When rainfall is predicted they should have the ability to adjust the construction sequence to allow for the implementation of soil stabilization and appropriate sediment control measures prior to the onset of any rain.

When construction activities must be changed, the changes should be discussed at the project's coordination meetings or directly with the project site manager/inspector. These discussions should occur prior to implementing the changes and if necessary, the schedule should be amended in advance to reflect those changes and maintain management control. Orderly modifications ensure coordination of construction activities and installation of the storm water quality measures. Orderly modifications also minimize the potential for erosion and sedimentation problems. If major changes are necessary, it may be beneficial to send a copy of the revised schedule to the local permitting authority.

Developing a Construction Sequence Schedule

Developing a construction sequence schedule is very similar to project planning and design and incorporates many of the same principles. Some of the more important factors to consider when developing a construction sequence schedule include weather, soil conditions, growing season, and phasing of the project to minimize the amount of area to be disturbed at any one time.

At a minimum, a construction sequence schedule should show the following:

- Principal development activities.
- Storm water quality control measures to be installed.
- Specific measures that should be in place before other activities are begun.
- Compatibility with the general construction schedule of the overall project.

In general, a construction sequence schedule is developed by first listing all construction activities associated with the project. This list should include any off-site activities associated with the project. A construction activity list will typically include but is not limited to preconstruction activities, access to the construction site, perimeter controls, storm water runoff control, land clearing and grading, storm water conveyance system installation, infrastructure construction/installation, and final stabilization. Other activities that might be included as subitems in the list are activities that may require non-storm water discharges such as dewatering, saw cutting, grinding, drilling, boring, crushing, blasting, painting, hydrodemolition, mortar mixing, pavement cleaning, etc.

The second step in developing a construction sequence schedule is to establish the sequencing of construction activities and a general timetable for the start and completion of each item such as site clearing and grubbing, grading, excavation, paving, foundation pouring, utilities installation, etc. Development of the timetable should take into consideration the effect extended periods of rain may have on each specific soil-disturbing activity and on restabilization activities. Where feasible, adjust construction activity time frames to minimize soil exposure during anticipated rainy periods which frequently occur in spring and early autumn.

The third step in developing a construction sequence schedule is to list the erosion control measures, sediment control measures, post-construction storm water measures, and non-storm water pollutant control measures associated with each construction activity listed in step one. Other control measures should include tracking control measures, wind erosion control measures, and provisions for waste management and materials pollution control. The schedule should address but is not limited to the deployment of each of these measures in relation to land-disturbing activities and other operational schedules associated with the construction project. The schedule should provide details for the deployment of these measures in both dry weather conditions and extended periods of rain.

The next step is to merge everything into a logical sequence that will provide a practical and effective method of installation. If the schedule becomes too large or complicated, multiple plan "windows" or multiple sheets can be used for clarity.

The final step of developing a construction sequence schedule is to incorporate it into the storm water pollution prevention plan.

Often, it is easier to develop a construction sequence schedule by answering a series of questions. For example, one of the first basic questions to ask is, "**Will the removal of existing soil surface ground cover leave the site vulnerable to accelerated erosion?**" In most instances, the answer to this question will be yes. The next basic question that might be asked is, "**Can this project be developed in phases?**" If the answer to this question is yes, it might be beneficial to develop a separate schedule for each phase of the project. The following discussion addresses various types of construction activities and associated concerns that need to be taken into account when developing a construction sequence schedule.

Preconstruction Activities

The purpose of preconstruction activities is to evaluate and protect important site features such as trees, vegetation, unique site features, etc. that may be associated with construction activities.

The preservation of trees, existing vegetation, unique site features, etc. on a project site requires forethought and planning in order to ensure that these features are not damaged or destroyed by construction activities. Frequently these resources are destroyed in the interval between purchasing the property and completing construction activities. Damage to these areas is generally the result of direct contact with construction equipment. However, damage can also be caused as a result of root zone stress from filling, excavating, or compaction of soil within and around root zones and tree driplines. It is quite common to see dead trees within a year or two after their rooting system has been damaged. This generally leads to costly removal and can result in property damage if the trees fall. Therefore, storage of equipment, vehicles, and construction materials under trees or on other areas to be protected should be prohibited.

Preservation/protection of important project site features begins with the development of a construction sequence schedule that identifies measures which can be used to manage construction activities, or at the very least minimize damage, in these areas. As the preconstruction activity section of a schedule is developed, it is important to evaluate what measures can be used to minimize the clearing of existing vegetative cover; maximize the preservation of wetlands, sensitive areas, etc.; and/or buffer stream corridors. Areas down slope of building sites should be evaluated to determine if they should be preserved or protected for the purpose of flow control and water quality enhancement via flow dispersion through the native vegetation.

Following are some basic but very important questions that often need to be answered when developing a construction sequence schedule for preconstruction activities. It must be noted that this list is not all inclusive and other questions may need to be addressed, depending on the scope of the proposed construction project.

The first basic question to ask in regard to developing a schedule for preconstruction activities is, "**Does this project require working around buried utility lines?**" If the scope of a project requires working in and around underground utilities, the construction sequence schedule should identify measures such as contacting the appropriate underground plant protection agency [e.g., Indiana Underground Plant Protection Service (also known as "Holey Moley") 1-800-382-5544] at least two working days before initiating any construction activities.

Another key question that should be addressed on projects associated with open waterbodies, wooded areas and wetlands is, "**Does the project site owner need any local, state, or federal permits to work in or around these areas?**" Various permits are frequently required if there is potential for a project to degrade water quality or have a significant impact on endangered plant or animal species. If permits are needed the sequence schedule needs to allow sufficient lead time for permit application and issuance of the permit by the appropriate regulatory agency.

"**Are there any existing site features, sensitive areas, unique areas, etc. that need to be preserved on the project site?**" is another question that should be addressed before starting construction on a project site. Where applicable, construction sequence schedules should identify measures that can be deployed on the construction site to prevent, or at the very least minimize, damage from construction operations. Placement of temporary fencing around tree driplines and placement of thick protective mulches over rooting zones are just two examples of management measures that might be used at a construction site to minimize damage to trees that are to be protected. A construction sequence schedule might also specify that physical barriers be erected around on-site sewage disposal absorption fields, unique cultural areas, areas with aesthetic value, etc. before beginning any land-disturbing activities of the project.

Another preconstruction activity question to ask is "**Are there any existing areas suitable for use as vegetative filter strips or riparian buffers?**" Areas suitable for use as vegetative filter strips or riparian buffers should be protected. The sequence schedule should identify measures that contractor(s) can install to protect these areas from construction traffic and from being used as materials storage areas. Again, the most obvious measure for protecting these types of areas is to clearly mark the area(s) and erect a physical barrier around them.

One more key preconstruction activity question that needs to be addressed is, "**Does this site require the use of on-site waste disposal facilities for developments that will not be served by sanitary sewers?**" Areas of a project site that are identified for use as on-site sewage disposal facilities should be protected to ensure the soil's ability to process or treat sewage effluent. In these situations the construction sequence schedule should identify appropriate measures such as temporary fencing that can be used to protect designated areas from vehicular traffic, excavating, or filling.

Areas to be preserved should be shown on all property maps and should be clearly marked, preferably with a physical barrier, during clearing and construction on the project site. If feasible, areas to be preserved should be placed in a separate tract or protected through recorded easements.

Construction Site Access

This item is applicable to construction entrances, construction routes, equipment staging areas, and employee parking areas, etc.

The purpose of installing construction access protection measures is to minimize the potential of soil being tracked onto public or private roadways from vehicles as they exit an active construction site.

When a site is opened up, care must be taken to avoid damaging valuable trees, disturbing designated buffer zones, and creating avenues for sediment-laden storm water runoff to flow off of the project site.

Construction site access for construction vehicles, contractors and their employees, and materials vendors is normally the first land-disturbing activity associated with a project site. Therefore, steps should be taken to provide stable ingress/egress and minimize the potential for the tracking of soil onto public or private roadways.

Two basic questions to ask for this phase of construction are, "**Is there potential for vehicles (i.e., construction vehicles, contractor vehicles, materials vendors vehicles, etc.) to track soil from the project site onto public or private roadways?**" and "**Do on-site construction routes, construction vehicle staging and maintenance areas, designated employee parking areas, etc. need to be stabilized to prevent tracking of sediment onto public and/or private roadways?**" If the answer to either of these questions is yes, the schedule should identify appropriate measures to minimize the potential for tracking, such as stabilized ingress/egress pads, staging areas, etc., and specify that these measures must be installed before proceeding with any additional earthmoving activities. In instances where it is necessary to remove trees, shrubs, and/or brush to achieve site access and/or install perimeter control measures, clearing and grubbing should be limited to those areas needed for installation of the ingress/egress pads and perimeter storm water measures.

Perimeter Protection

The purpose of installing perimeter protection measures is to minimize the potential for off-site sedimentation when mass earthmoving activities are taking place.

Perimeter protection is a key element of most construction sequence schedules. Typically this is thought of as providing erosion and sediment control protection at the perimeter of the overall project site. However, perimeter protection can also be a key element in protecting areas adjacent to active construction zones within the project site itself.

When developing the perimeter protection section of a construction sequence schedule, the first goal should be to protect all adjacent properties from potential erosion and sedimentation that may result from the active construction project. Two basic questions to ask in regard to this section of the schedule are, "**Is there potential for storm water runoff to discharge from the project site and cause erosion or sediment damage on adjoining properties or affect waters of the state of Indiana?**" and "**Will storm water runoff from adjoining properties interfere with land-disturbing operations on the project site?**" If the answer to either of these questions is yes, then the construction sequence schedule might specify the installation of temporary or permanent measures such as the protection of existing vegetative filter strips, establishing new vegetative filter strips, installing sediment barriers/filters, constructing diversion ridges and/or channels, constructing sediment traps/basins, etc.

In regard to perimeter protection as it applies to active construction zones within the project site, again there are two basic questions to ask. The first question that must be answered is, "**Will storm water runoff from up slope areas interfere with land-disturbing operations?**" The second question that needs to be answered is, "**Will the discharge of sediment-laden water from the active construction zone create problems on other areas of the project site?**" If the answer to either of these questions is yes, the construction sequence schedule should specify measures such as the protection of existing vegetative filter strips, establishing new vegetative filter strips, installing sediment barriers/filters, constructing temporary diversion ridges and/or channels, constructing temporary sediment traps/basins, etc. that can be used to control and treat the storm water runoff.

The measures specified in any perimeter protection phase of a construction sequence schedule should be installed before beginning any land clearing and grading operations.

Storm Water Runoff Control

Storm water runoff control measures serve two primary purposes. They are used to divert storm water runoff away from active construction areas and to divert sediment-laden storm water runoff from construction zones into sediment-trapping devices.

When developing a construction sequence schedule, it will most likely be necessary to specify measures for the control of storm water runoff. As is so often typical, measures selected for one construction phase may overlap with one or more of the other construction phases. For example, as with perimeter protection, one of the questions that must be asked when developing this section of a construction sequence schedule is, "**Will storm water runoff from adjacent, up slope areas interfere with construction activities?**" If the answer to this question is yes, measures such as temporary diversion dikes and drainage swales might be specified for the purpose of diverting storm water runoff away from and/or around construction areas.

A second question to answer when developing a schedule for this phase of construction is, "**What measures do contractors need to install to divert sediment-laden storm water runoff from active construction areas into sediment trapping/treatment devices?**" In this situation, the construction sequence schedule might specify the installation of temporary or permanent diversions, temporary slope drains, etc.

Key storm water runoff control measures should be located in conjunction with sediment-trapping devices such as those specified in the perimeter protection section of the construction sequence schedule. Measures should be selected based on their ability to divert storm water runoff from undisturbed areas away from sediment traps/basins and divert sediment-laden storm water runoff into the traps/basins. Storm water runoff control measures should be installed, stable, and discharge to a stable outlet prior to opening any major areas for mass clearing or grading.

Construction sequence schedules must be flexible enough to allow for the installation of additional storm water runoff control measures and sediment-laden storm water runoff treatment measures which may be needed as grading operations progress across the project site.

Land Clearing & Mass Grading

This item is applicable to cutting, filling, and grading operations.

All construction site access, perimeter protection, and storm water runoff control measures should be in place, stabilized, and where applicable, have a stable outlet. It is important that these measures are in place to contain sediment, minimize off-site sedimentation, and treat sediment-laden storm water runoff as major land clearing and earthmoving activities commence. These measures must also be maintained throughout all phases of construction to ensure their effectiveness.

Principal sediment traps, basins, filters, barriers, and storm water runoff control measures should be installed and stabilized before any major site clearing or grading takes place.

When developing a construction sequence schedule for this phase of a construction project, try to schedule major grading operations during periods of minimal rainfall. Allow enough time before anticipated rainy periods to stabilize graded soils with vegetation or other nonerosive measures and/or install sediment-trapping devices. Leave adjoining areas planned for development or designated borrow/disposal areas undisturbed as long as possible, taking advantage of their ability to serve as natural buffer zones. On larger projects, phase land-disturbing activities to reduce the amount of soil exposed to erosive forces. Reducing the amount of surface area exposed to soil erosion will minimize the sediment yield and will often allow for the use of smaller storm water quality measures.

A basic question to ask when developing this section of a construction sequence schedule is, "**What measures will contractors have to utilize to contain soil stockpiles on the construction site?**" As soil materials are stripped and relocated on the project site they should be stockpiled in areas that will not interfere with other construction activities or in areas where they might cause damage to adjoining properties, waterways, or waterbodies. The construction sequence schedule should identify measures to contain and/or stabilize the soil stockpiles. For example the schedule might specify the installation of sediment barrier measures along the down-slope side of all soil stockpiles/borrow areas prior to placement of the stockpiles or removal of any material from the borrow area. The construction sequence schedule may further require the application of temporary cover such as temporary seeding, mulching, or covering of the soil stockpile with an artificial cover.

"**Will any construction areas be inactive for a period of 15 days or more (local ordinances may be more restrictive)?**" is an important question to answer when developing a construction sequence schedule for land clearing and mass grading construction activities. If the answer to this question is yes, the sequence schedule should identify measures appropriate for the season that can be used to temporarily stabilize the inactive areas.

Clearing, grubbing, and construction activities typically increase storm water runoff and can make streambank and shoreline stabilization work more difficult and costly. Therefore, another key question to ask is "**Are there existing water features such as streams, rivers, lakes, wetlands, etc. on the project site that need to be protected during clearing and grading operations?**" If the answer to this question is yes, the schedule should identify streambank and/or shoreline stabilization measures that should be installed and stabilized before proceeding with additional land-disturbing activities. It is usually best to schedule this work as soon as weather conditions permit.

"**What measures do contractors need to install to contain sediment on-site as mass earthmoving takes place?**" is still one more vital question that should be addressed in a construction sequence schedule. The schedule should identify erosion and sediment control measures, including but not limited to temporary seeding, sediment traps and basins, swale and channel protection, and temporary slope protection, that should be installed prior to or immediately following rough or finished grading operations. For example, the schedule might require temporary seeding on all graded areas that will be inactive for seven days or more. Furthermore, it might specify that seeding be done daily while the soil is still loose and moist, or at a minimum of weekly. On larger projects, the sequence schedule should incorporate staged seeding and revegetation of graded slopes as work progresses across the project site.

Flexibility of a construction sequence schedule is particularly applicable to this phase of a construction project. Timely installation of additional storm water runoff control and treatment measures not shown on the construction plans can be very effective in controlling erosion and sedimentation during clearing, grubbing, and grading operations. Therefore, a construction sequence schedule should be flexible enough to allow for the installation of additional storm water measures as needed.

Storm Water Runoff Conveyance System

This item is applicable to drainage swales, open channels, storm sewers, etc.

Storm water runoff conveyance systems should be installed early in the mass grading phase of construction and the main conveyance system used to convey storm water runoff through the development site without causing erosion.

Construction of the storm water conveyance system for a project often occurs in conjunction with mass grading activities or in the period just after achieving rough grade of the project site. It is generally best to install the main runoff conveyance system as early as possible in the land grading process and use it to manage and convey storm water runoff through the development. Controlling storm water runoff from the active construction zone will help reduce the erosion potential and allow for the placement of storm water treatment measures for the removal of sediment at strategic locations on the project site.

There are two primary questions that need to be addressed when developing the construction sequence schedule for this phase of construction. The first question is, "**What measures are required to prevent erosion/scour at storm water drainage system discharge points?**" Storm water from the conveyance system must be discharged to a stable outlet so that it does not cause erosion in the receiving channel or to the banks of the receiving basin or pond. Therefore, the construction sequence schedule should identify appropriate storm drain outlet protection measures, such as riprap over geotextile fabric, for each respective storm drain outfall. In the event that it is not feasible to construct and stabilize the outlet because of unavailable end sections or other materials or there is a delay in the installation of permanent outlet protection, the schedule should specify that temporary riprap outlet protection be installed until the outlet can be permanently stabilized.

Construction sequence schedules should specify that installation of the storm water runoff conveyance systems commence at the discharge (outlet) end of the storm drain system and proceed up slope, installing and protecting storm drain inlets as they are installed. This allows for placement and stabilization of storm drain outlet protection prior to discharging any concentrated flow into the receiving channel, basin, or pond. Constructing the drainage system in this manner reduces the potential for erosion/scour in the receiving channel, basin, or pond and generally allows contractors to work under dry conditions because they are working up slope, away from conveyance system drainage discharges. The construction sequence schedule should require that open drainage channels or swales be brought to final grade as soon as possible and stabilized immediately after construction.

The second question that needs to be addressed is, "**What measures can be incorporated into the project to minimize or eliminate the introduction of sediment and other storm water contaminates into the functional storm sewer system or drainage system?**" A construction sequence schedule should identify appropriate storm drain inlet protection measures designed to keep sediment and other suspended solids out of drainage system drop inlets, curb inlets, and culvert pipe inlets. Measures should be selected based on their ability to trap sediment in shallow pools without creating a safety hazard on the construction site and to allow flood flows to safely enter the storm drain system. Examples of measures that might be used to accomplish this goal include excavated drop inlet protection, block and aggregate curb inlet protection, geotextile fabric drop inlet protection, etc. A construction sequence schedule should also specify that storm drain inlet protection devices must be installed as soon as each respective storm drain inlet becomes functional.

Surface Stabilization

Surface stabilization should occur throughout the life of the project. Temporary and permanent stabilization measures should be identified for all seasons of the year.

Surface stabilization is one of those activities that can be integrated throughout the life of a construction project. Surface stabilization generally involves the application or installation of temporary or permanent storm water quality measures to minimize erosion from unvegetated areas such as rough graded areas, soil stockpiles and borrow areas, and building pads. Two basic questions that need to be addressed during this phase of construction are, "**What are the measures that need to be deployed on this project to control erosion and treat sediment-laden storm water runoff?**" and "**What are the measures needed to stabilize unvegetated areas that will be inactive or idle?"**

In regard to the first question, the construction sequence schedule should identify measures appropriate for the season and associated weather conditions, including measures that can be deployed to control erosion and sedimentation caused by unseasonal rainfall, wind, and/or vehicle tracking during a dry season. For example, the schedule might require surface stabilization on unvegetated areas within a specified time frame following the completion of earthmoving activities or one day prior to the onset of precipitation, or it might require temporary seeding and/or mulching during extreme weather conditions with permanent vegetation measures delayed until a more suitable installation time.

A construction sequence schedule might address the second question listed above by requiring that areas scheduled to be idle or inactive for seven days or more be seeded with a temporary vegetative cover at the end of each workday while the soil is still loose and moist, or that these areas be protected with an anchored mulch cover.

Infrastructure Activities

This item is applicable to roads, utilities, etc.

Major utility installation should be done during periods of minimal rainfall and when feasible, should be completed before starting the building construction phase. Installing utilities during dry weather minimizes rutting and damage to any existing measures the project site owner has installed.

Infrastructure installation should be coordinated with other development activities so that all work can take place in an orderly manner and on schedule. Experience shows that careful project scheduling improves efficiency, reduces cost, and lowers the potential for erosion and sedimentation problems.

Unfortunately, even with the best of planning, delays in the installation of infrastructure often occur and should be anticipated. In anticipation of these delays, the construction sequence schedule should include provisions for temporary seeding and/or mulching of all graded areas immediately following rough grading. This minimizes the potential for erosion of the construction site yet still allows for the installation/construction of infrastructure at a later date. Installation of infrastructure into these seeded areas will have little impact on the existing vegetation.

Development of a construction sequence schedule for the infrastructure phase of a construction project should address questions such as, "**Do any construction activities have to cross open drainage channels and/or open waterbodies or wetlands?**", "**Can utility installation operations be timed to coincide with dry weather conditions?**", and "**Will any areas require dewatering operations?**"

If infrastructure construction must occur in or around any open drainage channel or open waterbody, the construction sequence schedule should identify measures that the contractor(s) can use to isolate the work area from the open waterbody, streambank, or shoreline. The construction sequence schedule should also identify storm water management measures that can be used to minimize erosion and treat sediment-laden water which may flow from the construction zone. If directional boring is the method of choice for crossing waterbodies, the construction sequence schedule should identify measures that can be used to manage and treat water discharges from the drilling operations.

On some project sites it may be necessary to dewater open excavations as the infrastructure is installed. In these situations the schedule should identify measures for the treatment of any sediment-laden water that must be pumped from the open excavations. For example, the schedule might specify that sediment-laden water be pumped into a temporary dewatering structure or into a pump discharge bag before it is allowed to discharge into any waterbody. Where possible, it can be advantageous to adjust the construction sequence schedule so that installation is done during drier periods of the year. To the greatest extent practical, the schedule should provide for daily backfilling of open trenches, including seeding and mulching of work areas, as trenching progresses.

Building Construction

As with infrastructure activities, building activities should be coordinated with other development activities so that all work can take place in an orderly manner and on schedule.

Development of a construction sequence schedule for this phase of construction requires answering the basic question of, "**What storm water quality measures do building contractors need to install on individual building lots to minimize erosion, prevent off-site sedimentation, and minimize the introduction of potential pollutants to storm water runoff?**" The construction sequence schedule should identify appropriate measures to control erosion and contain sediment on the individual building sites as home/building construction takes place. For example, the construction sequence schedule might specify the use of storm drain inlet protection devices if the building site is in close proximity to a storm drain inlet. The next item in the sequence might specify the installation of perimeter sediment barriers/filters and stabilized ingress/egress pads to minimize the amount of sediment washed or tracked from individual building sites to road surfaces, storm sewers, and/or established grassed waterways. The schedule could then require selective placement of dumpsters and other appropriate disposal containers for the proper disposal of construction materials, solvents, etc. and identification and marking of concrete washout disposal areas.

Landscaping And Final Cover

This item is applicable to topsoil application, permanent seeding and mulching, sodding, and planting shrubs and trees.

Landscaping and final stabilization is the last major construction phase of any project. Topsoil stockpiling, tree preservation, undisturbed buffer areas, and well-planned road locations established earlier in the project may determine the ease or difficulty of this activity.

At this stage of a project, the construction sequence schedule should identify appropriate permanent stabilization measures for all remaining unvegetated areas, including borrow and disposal areas, and specify an installation timetable for each of the measures. The schedule should allow for the establishment of permanent vegetation during appropriate planting times for the vegetation specified in the plans.

In addition to permanent stabilization measures, the schedule should provide for the removal of all remaining temporary storm water management measures after construction, final grading, landscaping, and permanent stabilization has been completed and all disturbed areas up slope of the temporary measures have been properly stabilized. The construction sequence schedule should specify that sediment be removed from sediment basins/traps and that the sediment be incorporated into the topsoil, not just spread on the soil surface.

Post-Construction Storm Water Quality

There will be a variety of issues associated with the post-construction land use of a project. The two primary issues that are typically addressed are pollutants associated with the land use and storm water quantity. Each project will have a unique set of storm water measures that will be required to address quality and quantity.

The installation of post-construction storm water measures should also be part of the construction sequence schedule. Erosion control measures should be planned and implemented as a management tool to reduce the generation of sedimentation. Measures that are targeted to manage or control runoff and to trap sediment should clearly be scheduled for implementation prior to land disturbance. The schedules described for erosion and sediment control do not necessarily apply to the installation of post-construction storm water management measures.

The installation of post-construction storm water measures is not necessarily related to timing of the land-disturbing activities. Post-construction measures can be installed at any phase of the project. If contractors are working in a specific area it may be more efficient to install the measure to coincide with the work activity. The most appropriate time may coincide with the installation of infrastructure. In other situations, it may be best to wait to install the measure towards the end of the project. Part of this decision process will be directly related to the type of measure that has been selected. The plan designer needs to be cognizant that some post-construction storm water measures may be subject to failure or high maintenance requirements if installed when the overall activity at the site has the potential to generate sediment loads that could plug the system with excessive sediment.

There are two primary questions that need to be addressed when developing the construction sequence schedule for post-construction storm water measures. The first question is, "**What measures can be installed during the early stages of construction activity that will not be negatively impacted by sediment from construction activity?**" For example, it may be opportune to install a storm water basin early in the project and modify the design to act as a sediment basin. Prior to the basin being utilized for its post-construction intent, sediment should be removed to re-establish the design storage capacity and structural modification implemented to return the basin to its original design.

The second question is, "**What measures would be subject to failure if installed during active construction?**" The second part to this question is, "**If a measure is installed, can appropriate precautions be taken to reduce the sediment load that is directed to the measure?**" There are several measures that are subject to failure and are not adapted to the types of sediment loads that are associated with active construction. If these conditions exist, maintenance can often be costly or may even require reinstallation of the measure. Infiltration measures are one example of a measure that is subject to failure under these conditions. If measures subject to failure are installed during active construction it would be extremely important that the drainage area above the measure is stabilized or that an effective sediment control measure or measures are installed to protect the integrity of the infiltration measure. The plan should also specify provisions to isolate construction activity from areas that could compromise the measure.

The plan designer should carefully evaluate when it is best to schedule the installation of each post-construction storm water quality measure. The schedule of implementation measures will be specific to the measure and should be based on activities that need to be performed to maintain the long-term functionality of the measure.

Non-Storm Water Discharges

Construction sequence schedules often overlook or do not address non-storm water discharges associated with dewatering, saw cutting, grinding, drilling, boring, crushing, blasting, painting, hydrodemolition, mortar mixing, pavement cleaning, etc. The cumulative effect of water discharges from these operations can have a bearing on water quality and therefore should be addressed in the sequence schedule.

When there is potential for surface water or ground water contamination from non-storm water discharges associated with construction activities on the project site, the construction sequence schedule should identify measures that can be used to collect and treat the discharges. For example, when there is a potential for wet excavations, the schedule should provide for the discharge of sediment-laden water into an appropriately sized sediment trap or basin, a dewatering treatment/filter structure, or pump discharge filter bag before allowing it to discharge into a waterbody or off-site storm sewer system.

Examples of a Construction Sequence Schedule

Construction sequence schedules can be developed in many different formats. The most common forms of construction sequence schedules are bar charts, numeric listings, and tables. At the end of this section is an example of each format showing a hypothetical construction sequence schedule that might be associated with a construction project. It must be noted that the activities listed in these examples do not usually occur in any specific linear sequence and that schedules will vary due to the type and scope of the project, weather conditions, and other unpredictable factors. It is important to note that every set of construction plans should have a proposed construction sequence schedule tailored to the specific project site.

In the bar chart format example, construction activities are listed down the left side of the chart and projected time frames are listed across the top of the chart. Storm water measures are listed as sub-items under each of the respective construction activities with the appropriate time frames marked in the body of the chart.

In the numeric list format example, construction activities are listed in a numerical sequence.

In the table format example, the construction activities are listed in the first column. The second column lists the various storm water measures associated with each construction activity. Column three identifies the location of the respective control and treatment measures and the timing of installation is identified in the last column.

No matter what format the plan designer chooses, it is important to keep in mind that the construction sequence schedule must be very flexible because there is no sure way to predict weather delays or delays in the permitting process.

Example of a Bar Chart Construction Sequence Schedule for a Residential Project (Land-Disturbance & Infrastructure Phase)

	Construction Sequence Schedule Time Frame													
Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Construction Sequence														
Preconstruction Activities (evaluation/protection of important site features):														
Preconstruction conference														
Preconstruction actions														
Contact utility locater														
Protect existing streams, lakes, wetlands, etc.														
Protect other important & aesthetic features														
Construction Access (construction entrances, construction routes, equipment parking areas):														
Install gravel construction entrance														
Install gravel equipment parking area(s)														
Perimeter Controls:														
Install sediment barriers & filters (silt fence, etc.)														
Install outlets & outlet protection devices														
Install sediment traps & basins														
Initial Land Clearing and Grading Activities:														
Grub & clear vegetation														
Strip & stockpile topsoil														
Stabilize topsoil stockpiles														
Secondary Land Grading Activities (cutting/ filling/ grading, drains, sediment traps, barriers, diversions, surface roughening):														
Runoff Control (outlet protection, sediment traps & basins, diversions, perimeter dikes, water bars):														
Install outlets & outlet protection devices														
Construct on-site sediment traps & basins														
Construct diversion channels, berms, water bars, etc.														

Example of a Bar Chart Construction Sequence Schedule for a Residential Project (Land-Disturbance & Infrastructure Phase) [*continued*]

	Construction Sequence Schedule Time Frame																		
Week	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Construction Sequence																			
Runoff Conveyance System (stabilized streambanks, storm drains, inlet and outlet protections, channels):																			
Install storm sewer system			■	■	■	■													
Protect storm drain inlets				■	■	■													
Construct swales							■	■	■										
Install sediment traps									■										
Seed and/or mulch swales									■	■									
Excavate Subsoil to Grades Shown on Plans:																			
Stockpile subsoil in designated areas											■								
Stabilize subsoil stockpiles											■								
Temporary Surface Stabilization:																			
Seed and/or mulch disturbed areas daily/weekly	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			
Permanent seed all areas at final grade	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Install Infrastructure:																			
Construct streets/roadways												■	■	■	■				
Install curb and gutter														■	■	■			
Pave streets/roadways																■	■		
Install utilities															■	■	■	■	■

Example of a Bar Chart Construction Sequence Schedule for a Residential Project (Building Construction Phase)

	Construction Sequence Schedule Time Frame									
Week	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Construction Sequence										
Building Construction (buildings, utilities, paving):										
Protect storm drain inlets				■						
Install stone access drive				■						
Install perimeter protection (silt fence)				■						
Protect & maintain drainage swales				■						
Excavate for foundations and footings				■						
Construct building(s)				■	■	■	■			
Install downspout extenders								■		
Seed & mulch lawn								■		
Final Shaping/Landscaping/Stabilization:										
Apply topsoil and soil amendments								■		
Plant trees and shrubs								■	■	
Permanent seeding & mulching, sodding									■	
Maintenance of Erosion & Sediment Control Practices:				■	■	■	■	■	■	■
Remove temporary structural measures, Seed and mulch any remaining unvegetated areas										■

Example of a Numerical List Construction Sequence Schedule for a Residential Development

NOTE: The soils engineer will be on site to inspect and certify all grading operations.

1. The site superintendent and/or the party that will be directly responsible for maintaining the sediment control devices must meet with the "Anywhere County" sediment control inspector for a preconstruction meeting at the site with a print of the approved sediment control plan prior to issuance of the grading permit.

2. Obtain grading permit from "Anywhere County Department of Environmental Resources."

3. Install stabilized construction entrance with mountable berm and 12-inch temporary corrugated metal pipe culvert. (1 day)

4. Clear and grub areas as necessary for the installation of sediment control devices as shown on this plan. (2 weeks)

5. Install the following sediment control devices and stabilize per temporary seeding specifications. (3 weeks)
   a. Install stone outlet structure #1, adjoining earth dike A-4 and silt fence (insert A, sheet 6 of 9).
   b. Excavate sediment basin #2 and use excavated soil to fill existing area draining to stone outlet structure #1. Compact and provide positive drainage as shown on insert A, sheet 6 of 9.
   c. Construct 240 feet of earth dike A-1 extending from north side of basin #2 and temporary swale shown on sheet 2 of 9.
   d. Install sediment traps and remaining basins, all remaining perimeter earth dikes, pipe culvert #8, all remaining stone outlet structures, all silt fences except on Block C, Lots 3 & 4 and Block D, Lot 23.
   NOTE: Do not install sediment control devices for utilities until work begins. Do not proceed to step #6 without approval of sediment control inspector.

6. Upon acceptance of sediment control, clear and grub site, starting with road right-of -way. (2 weeks)

7. Begin rough grading of site starting with roads. In the following areas, the roads shall be put on grade before completing grading in adjacent areas. (15 weeks)
   a. Bring Carlene Drive to grade from station 47+00 to 55+00 before grading on Lots 1-7, Block C. After Carlene Drive is on grade, earth dike A-1 and earth dike B-3 may be removed and the silt fence on Lots 2 and 3 installed, but only with the approval of the sediment control inspector.
   b. Bring Carlene Drive from Station 16+50 to 20+50 and area to east to grade. When this area is at grade, the side slopes shall be stabilized per the specifications. When area is stabilized, remove earth dike A-1 (sheet 4 of 9).

8. Install water and sewer. Provide sediment control for construction outside main perimeter sediment control devices. (8 weeks)
   NOTE: All sediment controls will be repaired the same day as utility construction.

Example of a Numerical List Construction Sequence Schedule for a Residential Development (*continued*)

9. Install storm drain as follows. (10 weeks)
   NOTE: Install riprap channel outlet protection in Parcel F (sheet 2 of 9) and Block B, Lot 1 (sheet 4 of 9) where first outfall discharges into stream. Start at lower end and work upstream.
   NOTE: All sediment controls will be repaired the same day as utility construction. Soils engineer will determine in field if underdrains are needed in Morley soils areas. Rough grading permit shall be resubmitted for approval by Department of Environmental Resources.

   a. Build endwall 57A and manhole 57 and pipe between the same. Install remaining storm drain line beginning at manhole 57 and working upstream.
      NOTE: Inlets 61 and 60 are to be bricked shut. Install riprap channel outlet protection at endwall 57A (sheet 6 of 9).
   b. Build inlet 54 and inlet 55 and pipe between the same. Install approximately 40 feet of 18-inch PVC pipe at inlet 54 and temporarily discharge it into Basin #7. Install remaining storm drain line beginning at inlet 55 and working upstream to structure #56.
      NOTE: Endwall 53B and manhole 53A and pipe between the same may be built at this time. Install remaining storm drain line beginning at manhole 53A and working upstream; however, the 18-inch reinforced concrete pipe between inlet 54 and manhole 54A must be bricked shut at inlet 54. Install riprap channel outlet protection at endwall 53B (sheet 7 of 9).
   c. Build endwall 47 and manhole 48A and pipe between the same. Brick shut 18-inch reinforced concrete pipe between these at manhole 48A. Install approximately 75 feet of 18-inch PVC pipe at manhole 48A and work upstream. Install riprap channel outlet protection at endwall 47. Once storm drain diversion is
      functioning, pipe culvert #8 may be removed (sheet 7 of 9).
   d. Build endwall 39 and manhole 46A and pipe between the same. Install remaining storm drain line beginning at manhole 40A and working upstream.
      NOTE: Inlets 43, 44, and 45 are to be bricked shut. Install riprap channel outlet protection at endwall 39. Provide inlet protection at inlet 41 (sheet 5 of 9).
   e. Build endwall 35 and manhole 36 and pipe between the same. Install remaining storm drain line beginning at manhole 36 and working upstream. Install approximately 165 feet of 15-inch PVC at inlet 38 and temporarily discharge it into trap #1.
      NOTE: Brick shut 15-inch reinforced concrete pipe between structure 37 and 36 at structure 37. Install riprap channel outlet protection at endwall 35 (sheets 2 and 5 of 9).
   f. Build manhole 32 and inlet 33 and pipe between the same. Install approximately 30 feet of 15-inch PVC pipe at manhole and temporarily discharge it into trap #6. Endwall 30 and manhole 31 may be built at this time.
      NOTE: Brick shut 15-inch pipe between structures 32 and 31 at structure 31. Install remaining storm drain line beginning at inlet 33 and working upstream. Install riprap channel outlet protection at endwall 30 (sheet 5 of 9).

Example of a Numerical List Construction Sequence Schedule for a Residential Development *(continued)*

g. Build inlet 26A and manhole 26 and pipe between the same. Install approximately 30 feet of 18-inch PVC pipe at inlet 26A and temporarily discharge it into trap #4.
   NOTE: Endwall 17 and manhole 18 may be built at this time. In one day, construct structure #24 and install approximately 30 feet of 18-inch PVC pipe and adjust in field to connect to temporary 18-inch PVC pipe that discharges from trap #4. Build pipe between structures 24 and 18. Install remaining storm drain line beginning at structure 24 and working upstream to structure 26A. Install riprap channel outlet protection at endwall #7 (sheet 4 of 9).

h. Build inlet 19 and pipe between inlet 19 and existing manhole 18. Install approximately 55 feet of 18-inch PVC pipe at inlet 19 and temporarily discharge it into trap #3. Brick shut 18-inch reinforced concrete pipe between inlet 19 and existing manhole 18 at inlet 19. Install remaining storm drain line beginning at existing manhole 18 and working upstream (sheet 3 of 9).

i. Build endwall 4 and manhole 8 and pipe between same. Install remaining storm drain line beginning at structure 6 and working upstream to structure 12. Install riprap channel outlet protection at structures 4, 12 and 13 (sheet 2 of 9).

j. Concurrently, starting at structure #10, build remaining storm drain line working upstream to structure #26.
   NOTE: Provide inlet protection at structures 14, 15, and 16 (sheet 2 of 9).

k. Build endwall 1 and manhole 2 and pipe between the same. Install remaining storm drain line beginning at manhole #2 and working upstream.
   NOTE: The 15-inch reinforced concrete pipe between manhole 3 and manhole 2 will be bricked shut at manhole 3. Install approximately 83 feet of 15 -inch PVC pipe at manhole 3 and temporarily discharge it into basin #2.

l. Build endwall 27B and manhole 27A and pipe between the same. Build remaining storm drain line working upstream starting at structure #27A. Brick shut 18-inch reinforced concrete pipe between structure 28 and 28A at structure 28. Install approximately 56 feet of 18-inch pipe at inlet 28 and temporarily discharge it into trap #5 (sheet 4 of 9).

10. Construct curb, gutter and sidewalks. Base pave the streets. (6 weeks)

11. Fine grade site and stabilize per the permanent seeding specifications. (3 weeks)

12. Upon site stabilization, flush storm drain systems then remove structure blocking and temporary storm drain diversions only with the permission of the sediment control inspector. (1 day)

13. Remove all sediment control devices, except sediment basin #8, only with permission of the sediment control inspector and stabilize per permanent specifications. For removal of trap #3, silt fence must be installed as shown on plan. (1 week)

14. When the area to basin #8 is stabilized, temporarily de-water the basin. The basin shall be filled starting at the upstream end of the basin and working towards the

Example of a Numerical List Construction Sequence Schedule for a Residential Development (*continued*)

dam. Grade to area as shown in Insert "B" on sheet 9 of 9 and stabilize per permanent seeding specifications. (1 week)
NOTE: Do not proceed to step #15 without approval of sediment control inspector.

15. Upon approval of grading and stabilization remove trap #9 including 42-inch barrel and 60-inch riser. Install riprap channel as shown in Insert "C." Stabilize per permanent seeding specifications. (1 week)

DEVELOPMENT OF A CONSTRUCTION SEQUENCE SCHEDULE

Example of a Table Construction Sequence Schedule for a Residential Project

Construction Activity	Measures Needed	Location of Measure	Timing of Installation
Preconstruction Activity			
• Work around existing utility lines	• Contact Indiana Underground Plant Protection Service ("Holey Moley") • 1-800-382-5544	-----	• Week 1
• Provide notification of actual construction start date to reviewing agency(s)	• Contact plan reviewing/ inspection agency(s)	-----	• Week 1
• Protection of important site features, sensitive areas, unique areas, etc.	• Fencing or other physical barrier	• Around perimeter of area(s) to be protected/preserved	• Week 1
• Protection of areas suitable for use as vegetative filter strips	• Fencing or other physical barrier	• Up-slope side of vegetative filter strip	• Week 1
• Protection of areas designated for on-site sewage disposal from compaction and disturbance	• Fencing or other physical barrier	• Around area(s) designated for use as on-site sewage disposal facilities	• Week 1
Construction Site Access:			
• Stabilization of site access drives to prevent or minimize tracking of sediment onto public or private roadways	• Aggregate ingress/egress pads	• At all points where vehicles enter and exit the site	• Week 1
• Stabilization of construction routes, construction vehicle staging and maintenance areas, designated employee parking areas, etc. to prevent or minimize tracking of sediment onto public or private roadways	• Aggregate staging pads • Stabilized construction routes • Dust control	• All staging and parking areas • Project site construction routes	• Weeks 1 and 2
Perimeter Controls:			
• Diversion of storm water runoff from up-slope properties away from the project site	• Perimeter dike	• Up-slope side of areas scheduled for grading and massive earthwork	• Week 2
• Collection and treatment of sediment-laden storm water runoff before it discharges onto properties down slope of the project site	• Permanent diversion • Sediment barriers/filters • Sediment traps/basins	• At locations where storm water may discharge from project site	• Weeks 2 and 3
• Diversion of storm water runoff away from the active construction zone	• Temporary diversion	• Up-slope side of active construction zone	• Weeks 2 and 3
• Collection and treatment of sediment-laden storm water runoff flowing from the active construction zone	• Temporary diversion • Sediment traps/basins	• Down-slope side of construction zone	• Weeks 2 and 3
Initial Land Clearing and Grading Activities:			
• Clearing and grubbing of vegetation	• Sediment barriers/filters • Sediment traps/basins • Diversions	• Down-slope side of active construction zones	• Weeks 2 and 3

Example of Table Construction Sequence Schedule for a Residential Project *(continued)*

Construction Activity	Measures Needed	Location of Measure	Timing of Installation
• Stripping and stockpiling of topsoil	• Sediment barriers/filters • Sediment traps/basins	• Down slope of active construction zones	• Weeks 2 and 3
• Stabilization of topsoil stockpiles	• Sediment barriers/filters • Temporary seeding • Mulching	• Perimeter of soil stockpiles • Over top of soil stockpiles	• Weeks 2 and 3
Secondary Land Grading Activities:			
Runoff Control (outlet protection, sediment traps & basins, diversions, perimeter dikes, water bars):	-----	-----	-----
• Construction of primary sediment traps and basins	• Sediment barriers/filters	• Down slope of active construction zones	• Weeks 3 through 6
• Construction of primary detention/ retention basins/ponds	• Sediment barriers/filters • Sediment traps	• Down slope of active construction zones	• Weeks 3 through 6
• Installation and stabilization of outlets for storm water drainage system	• Riprap outlet protection • Turf reinforcement mats	• Basin outlets • Storm drain outlets • Open channel outlets • Culvert pipe outlets	• Weeks 3 through 6
• Construction of diversion channels, berms, water bars, etc.	• Sediment barriers/filters • Sediment traps/basins	• Down slope of active construction zones	• Weeks 3 through 7
Runoff Conveyance System (stabilized streambanks, storm drains, inlet and outlet protection, channels):	-----	-----	-----
• Installation of storm sewer system	• Sediment barriers/filters • Sediment traps/basins	• Down slope of active construction zones	• Weeks 7 through 12
• Protection of storm drain inlets	• Drop inlet protection • Curb inlet protection	• Storm drain inlets • Culvert pipe inlets	• Weeks 7 through 12
• Stabilization of areas disturbed for storm sewer installation	• Temporary seeding • Mulching	• Areas where storm sewer lines have been installed	• Weeks 7 through 12
• Construction of drainage swales	• Sediment barriers/filters • Sediment traps/basins	• Down slope of active construction zones	• Weeks 7 through 12
• Stabilization of drainage swales	• Permanent seeding • Mulching	• Areas where construction of drainage swales has been completed	• Weeks 7 through 12
Excavate Subsoil to Grades Shown on Plans:	-----	-----	-----
• Rough grading and stockpiling of subsoil in designated areas	• Sediment barriers/filters • Sediment traps/basins	• Down slope of active construction zones	• Weeks 12 through 15
• Stabilization of soil stockpiles	• Sediment barriers/filters • Temporary seeding • Mulching	• Perimeter of soil stockpiles • Over top of soil stockpiles	• Weeks 12 through 15
Temporary Surface Stabilization:			
• Temporary surface stabilization of rough graded areas	• Temporary seeding • Mulching	• All rough graded areas that will be inactive for a period of seven days or more	• Weeks 2 through 19

Example of Table Construction Sequence Schedule for a Residential Project *(continued)*

Construction Activity	Measures Needed	Location of Measure	Timing of Installation
• Permanent surface stabilization of areas at final grade	• Permanent seeding • Mulching	• Detention/retention basins • Drainage swales	• Weeks 2 through 23
Install Infrastructure:			
• Cut in roads/streets and construct roadway subgrade/base	• Sediment barriers/filters • Sediment traps/basins	• Down slope of active construction zones	• Weeks 15 and 16
• Install curb and gutter	• Sediment barriers/filters • Sediment traps/basins • Curb inlet protection	• Down slope of active construction zones • Storm drain curb inlets	• Weeks 17 and 18
• Pave Streets/Roadways	-----	-----	• Week 19
• Install Utilities	• Sediment barriers/filters • Sediment traps/basins • Temporary seeding • Mulching	• Down slope of active construction zones	• Weeks 19 through 22
Building Construction:			
• Protection of existing storm drain inlets	• Drop inlet protection • Curb inlet protection	• Operational storm drain inlets	• Weeks 18 through 23
• Installation and stabilization of site access	• Stone ingress/egress pads	• At all points where vehicles enter and exit the site	• Weeks 18 through 23
• Installation of perimeter protection	• Sediment barriers/filters	• Down-slope side of construction areas	• Weeks 18 through 23
• Protection and maintenance of drainage swales/channels	• Sediment barriers/filters	• Down-slope side of construction areas	• Weeks 18 through 23
• Excavating for foundation footers	• Sediment barriers/filters	• Down-slope side of construction areas	• Weeks 18 through 23
• Construction of buildings/structures	• Sediment barriers/filters	• Down-slope side of construction areas	• Weeks 18 through 23
• Installation of downspout extenders	-----	• End of downspouts	• Week 18 through 23
Final Shaping/Landscaping/Stabilization:			
• Application of topsoil and soil amendments	• Topsoil salvage and utilization	• Unvegetated areas that are at final grade	• Weeks 21 through 24
• Planting of trees and shrubs	• Topsoil salvage and utilization	-----	• Weeks 21 through 24
• Final site stabilization	• Permanent Seeding • Mulching • Sod	• All remaining unvegetated areas	• Weeks 21 through 24
Maintenance of Erosion and Sediment Control Measures:			
• Removal of temporary storm water management measures and stabilization of remaining unvegetated areas	• Permanent seeding • Mulching	• Areas disturbed when removing temporary storm water management measures	• Week 24

Introduction to Construction Plan Implementation

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The success of any construction project starts with good construction site management and the use and implementation of the construction plans, including the storm water pollution prevention plan.

Good construction site management is key to the application of the principles and implementation of the storm water management measures specified in the storm water pollution prevention plan. This includes each measure being installed according to the sequence of construction, in the proper location(s), and according to design/installation specifications. Storm water management measures that are improperly installed may have little or no effect and potentially may cause more damage.

Implementation of the construction plans and the storm water pollution prevention plan through good construction site management can be a very cost-effective process. Following is a partial list of construction site management tips that should be implemented on every project site.

- Prior to beginning the project, review all permits and permit conditions associated with the project. It is important that all permits are secured prior to the initiation of any land-disturbing activity. If there are permits that have not been obtained or are in the process of being obtained, do not work in those areas that are directly related to the permit.

- In an effort to ensure construction plans are appropriately implemented it is important that contractors, subcontractors, and others involved in the project understand the objectives of the project. One way to achieve good coordination and communication is to hold a preconstruction meeting. Preconstruction meetings are discussed in more depth in the Preconstruction Meetings section on pages 5-9 in this chapter.

- Preconstruction meetings are an important part of implementing a construction plan. However, it is also important to conduct routine meetings throughout the life of the project to explain issues and coordinate activities associated with the construction process and the implementation of the storm water pollution prevention plan.

- Prior to initiating any land-disturbing activities, a representative for the project should walk the site with the construction plans in hand and mark the limits of construction that were established during the planning phase. Areas to be protected should be marked with rope, safety fencing (commonly orange colored), or surveyor flags. Signage can also be used to identify and explain limits of construction and areas that are to be protected from construction activities.

- Individuals responsible for the installation and maintenance of storm water quality measures must be skilled, experienced, trained, and have an understanding of the purpose and function of storm water quality measures. At a minimum, at least one individual should be assigned the responsibility of overseeing installation and maintenance of the storm water quality measures.

- Each storm water quality measure should be inspected for performance. In fact, the entire project should be monitored to assess the performance of each measure and the effectiveness of the storm water pollution prevention plan. When deficiencies are discovered, appropriate steps should be taken to repair, replace, or select alternative measures that adequately address the issue. Additional information for the development of a quality assurance plan and site inspections can be found in Chapter 6, "Developing & Implementing a Quality Assurance Program."

- The objective of storm water pollution prevention plans is to eliminate or reduce problems associated with storm water runoff. Plan designers do their best to anticipate project activities and site management issues that may be associated with the project. However, the nature of construction and project dynamics can heavily influence the need for modification or an amendment to the plan. It is not practical or possible to anticipate every conceivable situation that may occur during the life of the project. It is for this reason that every project should have a quality assurance plan. A project's quality assurance plan should outline specific requirements for the inspection and monitoring of the overall effectiveness of the storm water pollution prevention plan.

Storm water pollution prevention plans should be flexible documents and changes to the project should be anticipated. Most corrective actions and modifications will occur in the field. These changes may require modifications to the plans, especially when there is a change in design, construction operations, or maintenance activities that could have a significant effect on the discharge of storm water from the site. Modifications may also be required if an inspection indicates that the plan or a specific storm water quality measure is not effective at addressing storm water discharge or runoff management.

Regulatory agencies may require resubmittal of plans and approvals for plan modifications when changes must be made to a project. Therefore, project site managers and other representatives of the project should become familiar with local regulatory requirements for plan modifications and resubmittal.

PRECONSTRUCTION MEETINGS

Before any land disturbance occurs on a project site, it is important that all participants have a clear understanding of the project and associated construction activities. One method to ensure that the project will run smoothly and that construction activities are coordinated is to hold a preconstruction meeting. The intent of preconstruction meetings is to coordinate project activities in relation to the construction plans.

Typically preconstruction meetings are held after construction plans have been approved by regulatory agencies. This manual is focused on environmental and natural resource issues; however a preconstruction meeting is not limited to this topic alone and can be beneficial to the overall coordination of the project. The intent of this section of the storm water manual is to focus on coordination of storm water issues and environmental aspects of the project.

As noted above, all projects should start with a preconstruction meeting. Preconstruction meetings can prevent or preempt many problems commonly associated with construction sites. Preconstruction meetings are an opportunity for all interested parties to meet face to face. These meetings help establish working relationships and provide a strong foundation for open communication with all parties involved in the project.

Preconstruction meetings should focus on design components, storm water quality issues, environmental issues, and other project components that warrant interaction and coordination between parties involved in project development and implementation. Plans are often designed without considering the dynamics of a construction site or the manner in which a contractor will approach work at the construction site. From the contractor's perspective, "Does the plan make sense?" There should be dialogue between the plan designer and contractor(s) to exchange ideas and solutions. This dialogue is generally initiated by the plan designer. Project site managers and inspectors also have an interest in these discussions because eventually they will be responsible for implementation of the plan and overall management of the site. The closer the working relationship between all project participants, the more successful the project.

Potential participants in preconstruction meetings include but are not limited to project site owners or their representatives, plan designers, project engineers, site managers, general or primary contractors, construction foremen/managers, subcontractors, key construction staff, utility representatives, and local and state regulatory officials.

Construction plans should be the focal point of a preconstruction meeting. Participants should receive copies of the construction plans and have ample time to review them prior to the meeting. When reviewing the plans, participants should pay special attention to construction phases, design drawings, details and specifications of construction elements, the sequence of construction, and other key elements that are associated with the project.

Preconstruction Meeting Guidance

- Develop a meeting agenda.
- Introduce all attendees and identify their role in the project.
- Hold the meeting at or near the site. It can be advantageous to hold the meeting at a facility that enables formal presentations of project details. However, it is also important that time is spent walking the entire project area to familiarize everyone with the project and the site conditions.
- Take minutes of the meeting and record all issues and decisions. Assign responsibility for each action item and assign one individual to ensure that all actions are addressed according to schedule.
- Changes that are made during the meeting may need approval from the regulating entity. If those changes are required through plan modification or other means the project site owner or their representative should submit the information to the appropriate regulatory authority. Additionally, project changes may also prompt the need for amended or additional permits to conduct a specific activity. It is the responsibility of the project site owner or their representative to investigate the need for additional permits and obtain those permits.
- Develop a directory of all participants (see the Project Resource Directory section on pages 8-9 in this chapter).

Topics & Information to Be Covered

- Discuss the scope of the project, including goals and objectives.
- Designate individuals who will be responsible for critical issues associated with the project.
  - Identify who is responsible for the implementation of the storm water pollution prevention plan, including proper installation and maintenance of storm water quality measures.
  - Identify who will have daily responsibility for inspection of project activities on behalf of the project site owner.
  - Identify a designated individual(s) who will specifically communicate with regulatory agency personnel.
- Review the construction plans, including the storm water pollution prevention plan.

  - Discuss construction operations, including plans and schedules for clearing, grading, and cut and fill operations.
  - Identify and discuss the limitations of construction activities.
    - Identify all buffers and/or natural areas that are to be protected. Discuss the measures that have been identified for protection of these areas and re-enforce that these areas are not to be used for staging, parking, material storage, waste disposal, or other unintended uses.
    - Discuss all significant resources within the watershed and identify construction limits and storm water quality measures chosen to minimize environmental impacts to these resources.
  - Review and discuss storm water quality measures that are to be implemented, including location, design standards, installation procedures, and maintenance requirements.
  - Review and discuss the construction sequence, especially the relationship between land disturbance and the installation of appropriate storm water quality measures. All parties should understand the construction sequence. Elements of the construction sequence that may cause conflict in the overall operational procedures of the project should be discussed and addressed so that revisions to the plan can be made.
  - Explain phasing of any project operations.
- Identify and locate existing utilities. If utilities are to be relocated, coordinate the operation with the appropriate utility representative.
- Review all permits associated with the project.
  - Ensure that everyone has a clear understanding of permit conditions and requirements.
  - Verify that all appropriate permits have been obtained.
  - Explain the status of any permits that have not been applied for or that are pending approval. Explain the consequences and impact that the permit will have on operations if the permits are not issued before an activity begins.
- Describe the project's quality assurance program.
  - Explain the inspection schedule that will be implemented.
  - Explain the authority of the inspector and how project deficiencies will be addressed.

- Additional information regarding development of a quality assurance program can be found in the Developing & Implementing a Quality Assurance Program section on pages 11-21 in this chapter.

- Review procedures for handling and storage of on-site construction materials and proper emergency response protocols in the event there is a spill or leak.

- Review other specific items applicable to the project.

Topics & Information to Be Covered by Regulatory Authority

- Emphasize to all parties involved with the project that the storm water regulations are performance based and that they will be enforced.
  - All storm water quality measures should be installed according to the plans and the sequence of construction.
  - Additional storm water quality measures may be required beyond the scope of the plan to address those issues that could not be predicted during plan development.

- Explain the regulatory process to all parties.

- Make sure everyone understands regulatory procedures including submittal of paperwork and official notifications that will occur.

- Explain the process for changing or modifying plans. Discuss pre-approval of plan modifications and who is responsible for approving the modifications.

  NOTE: This process may vary based on local and state regulations because it is the responsibility of the regulatory agency to establish criteria and procedures in accordance with their ordinances, rules, and laws that establish their authority. In fact, some regulatory authorities may not require any pre-approval for the change or modification of plans.

- Advise participants that inspections for compliance will be conducted and explain the procedures that will be used to conduct inspections.

- Discuss the consequences of non-compliance.

Project Resource Directory

A project resource directory should be created for every project. A project resource directory is a document containing information that can be used to expedite response times to emergencies, project site problems, and other project-related issues. A typical project resource directory includes the names, mailing addresses, phone numbers, e-mail addresses, and fax numbers of various individuals involved in the project. The directory normally includes the project site owner, project engineer, primary contractor, site managers, project inspector, subcontractors, and regulatory and enforcement personnel. In addition to this information, the directory should include the responsibility of each individual.

If plan implementation and the project are to be successful, it is essential that everyone involved with the project understand the construction plans, their role and responsibility in the project, and the roles and responsibilities of others involved with the project.

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Responsibility for storm water management does not end with the installation of storm water measures. Storm water measures require a high level of maintenance if they are to function efficiently. In general, failure to monitor and maintain storm water quality measures is the primary reason for their failure. Therefore, to ensure that the storm water measures function as designed, a quality assurance plan should be developed and implemented on every project.

A quality assurance plan should outline site management strategies, including inspection and maintenance of the individual storm water management measures. It is also important to designate a person or persons responsible for implementing the quality assurance plan. They should be responsible for ensuring that storm water quality measures are installed at appropriate times and in a timely manner, that the measures are functioning properly, and that the measures are properly maintained.

This section of the storm water manual provides insight into the development and implementation of a quality assurance plan, including an inspection and maintenance program for the overall construction project. Maintenance requirements for individual erosion and sediment control/storm water management measures can be found in Chapter 7, and the requirements for individual, structural post-construction storm water management measures can be found in Chapter 8.

Contents of a Quality Assurance Plan

An effective quality assurance plan contains two key components. The first component focuses on coordinating plan implementation. The second component focuses on the inspection and maintenance of each storm water measure. Each of these components has specific criteria that should be included in their respective sections of the quality assurance plan. Following is a brief listing of some of these elements.

Elements that should be included in the plan implementation section of a quality assurance plan includes, but is not limited to:

- A description of the process that will be used to ensure long-term maintenance of storm water measures, including those implemented for erosion and sediment control.
- Backup contingency plans that can be implemented in the event that supplies are unavailable for the timely installation of specific storm water management measures and the name(s) of the individual(s) responsible for authorizing and performing emergency or corrective actions.
- Provisions for educating all parties associated with the project. Contractors will be involved in a wide array of construction activities throughout the project site and may observe deficiencies or problems. They should be aware of the importance of the quality assurance plan and who to contact when they have concerns.

Elements that should be included in the inspection and maintenance section of a quality assurance plan include but are not limited to:

- Identification of all storm water measures, including erosion and sediment control measures, and critical areas to be inspected.
- An inspection schedule for each construction activity and each storm water measure.
- Instructions for regularly scheduled maintenance and repair of each storm water measure, including the procedure for the repair, who is responsible for the repair, and who should be notified of the repair.

Responsible Staff or Personnel

The individual or individuals designated as the project manager/inspector responsible for implementing the quality assurance plan should be identified early in the process. This individual(s) should be knowledgeable and experienced in erosion and sediment control principles, storm water management, and the installation, function, and maintenance of all storm water measures. The quality assurance plan project manager/inspector should also be familiar with all environmental permits and permit requirements associated with the project.

The project manager/inspector should have a clear understanding of their responsibility to inspect and document site deficiencies, their authority to initiate changes in the field, and if there is a monetary limit associated with the required corrective actions they can initiate.

Once the authority of the project manager/inspector has been established, it should be made known to all contractors and subcontractors associated with the project. Regulatory inspectors should also be notified who the project site owner has designated as the project manager/inspector and what authorities and responsibilities have been granted to this individual.

Installation & Oversight

Project site management involves more than just implementing the storm water pollution prevention plan. It also requires that someone supervise and oversee the implementation of erosion and sediment control measures, on-site construction activities that may generate other pollutants, and post-construction storm water measures.

Project managers/inspectors should be familiar with the project's storm water pollution prevention plan, including the location of all storm water measures and when they are to be installed. He or she should also be knowledgeable about specific locations within the project site that pose a threat for the discharge of pollutants off-site or to a water of the state. In order to achieve full implementation of the plan, it is necessary for the project manager/inspector to coordinate all construction activities with contractors and subcontractors working on the project site. He or she should ensure that the plan is implemented in accordance with the project's construction sequence schedule and that appropriate storm water management measures are installed in conjunction with associated land-disturbing activities.

The project manager/inspector should oversee the installation of all storm water measures to ensure that they are installed according to the standards and specifications contained in the storm water pollution prevention plan. For the storm water measures to function efficiently and effectively, it is critical that they be continuously monitored and evaluated.

Inspection

It is not uncommon to have an excellent storm water pollution prevention plan only to find that an oversight was made in a specific area. The purpose of on-site inspections is to provide the project site owner and/or their representatives with a process to monitor and manage the construction project and address such oversights. Regularly scheduled inspections are essential to maintaining the efficiency and effectiveness of the construction site storm water measures.

An on-site inspection consists of evaluating all storm water measures to ensure they have been installed correctly and that they are functioning properly. Inspections are also a valuable tool for monitoring the implementation of the construction sequence schedule and ensuring that the storm water measures are installed at appropriate times.

To ensure the integrity of storm water measures, it is critical to identify measures that are in need of repair and to identify any areas where additional measures should be implemented to correct a problem. Installed measures will be of little or no use if they have not been properly maintained. Some common reasons why storm water measures often fail include:

- Measures were not adequately maintained.
- Extreme weather conditions.
- Damage from equipment operated by contractors and/or subcontractors.
- Inadequate analysis of the site.
- The design of the measure does not fit the site conditions.
- Measures were incorrectly installed.
- Measures are inadequately sized.
- Improper materials were used.

When implementing an inspection program, it is important to remember that storm water pollution prevention plans are dynamic documents and that it may be necessary to modify some storm water measures or even add additional measures throughout the life of the project.

One final thing to remember in regard to inspection programs is that they are one of the most effective methods for ensuring that all construction activities are in compliance with local, state, and federal regulations.

Inspection and Maintenance Timeline

Quality assurance plans should include a specific schedule for monitoring activities associated with the construction project. The plan should also outline procedures to assure that soil erosion and sediment control measures and storm water management measures are functioning properly.

Once construction activities have begun at a project site, it is not uncommon to have the focus of on-site personnel shift from the storm water pollution prevention plan to other issues associated with construction activities. Therefore, it is critical to establish and implement a schedule ensuring that routine inspections are completed in a timely manner. There are two types of inspections (routine and non-routine) that are critical to the success of a project.

Routine Inspections

Routine inspections are performed at regularly scheduled intervals to ensure that each storm water measure is functioning properly and that construction activities at the project site are in conformance with the storm water pollution prevention plan. At a minimum the entire project site should be inspected weekly during active construction. While this is the minimum requirement, there are several storm water measures that may require more frequent inspection. To maintain the integrity of these later measures, it may be necessary to adjust or increase the frequency of the inspection intervals. Inspection and maintenance guidelines for individual erosion and sediment control measures are provided in Chapter 7 of this manual. Structural post-construction storm water quality measure inspection and maintenance guidelines are provided in Chapter 8.

Non-Routine Inspections

Non-routine inspections are inspections that are conducted in response to a rainfall event or in anticipation of a rainfall event. Non-routine inspections should be conducted following each measurable rainfall event. As a general rule, measurable rainfall events are defined as one-half inch or more of precipitation. In some jurisdictions, the local regulatory authority may have more stringent rules that require more frequent inspections.

Non-routine inspections conducted following a measurable rainfall event are done to ensure that all storm water measures are performing adequately. The inspection should focus on identifying measures that need to be repaired or replaced and areas within the project site that may be contributing to off-site discharge of sediment or other pollutants.

Non-routine inspections conducted prior to a predicted storm event are done as a precautionary measure to ensure that all storm water quality measures are in working order. In most situations, it is easier to take corrective action before a rainfall event rather than following the event.

Conducting non-routine inspections requires monitoring rainfall events. The easiest way to achieve this is to install a rainfall gauge on the project site. Rainfall gauges should be unobstructed and located away from trees, buildings, and construction equipment. The gauge should be placed atop a sturdy stake or pole and should be emptied after each rainfall event. Rainfall records should be maintained as part of the quality assurance plan and project files. Rainfall data can either be entered directly on the inspection report or tracked on a separate data log.

In addition to routine and non-routine inspections consideration should be given to inspecting the project site after each phase of construction. Below is a list of general guidelines for establishing a construction phase inspection schedule.

- Initial inspections should be performed prior to land grading to ensure all required storm water quality measures have been installed according to the plan.
- Rough grading inspections typically occur during land grading operations and the installation of infrastructure.
- Storm water pollution prevention plan compliance inspections are conducted after sediment traps and other storm water management control measures have been installed and during seeding operations.
- Final grading inspections are conducted when all grading has been completed and drainage systems, paving, and infrastructure have been installed.
- Final stabilization inspections are completed to ensure that all temporary storm water quality measures have been removed, permanent vegetation is established, and permanent storm water quality measures are installed and functioning properly.

Conducting Inspections

Inspection programs can be implemented once an inspection schedule has been finalized and appropriate personnel are in place.

The quality assurance plan project manager/inspector should be familiar with the overall project site and the implementation of the storm water pollution prevention plan, including when all storm water measures are to be installed in relation to grading activities and other construction activities associated with the project. It is especially important that the project manager/inspector be familiar with areas of the project where there is potential for sediment and other pollutants to discharge from the site. This should include areas of concentrated flow or discharge points that have the potential to impact sensitive resources or adjacent properties. Areas of ingress/egress to the project site are another area that needs to be closely monitored and maintained to ensure that tracking of soil material from the site is minimized.

Following is a list of key elements that should be monitored and evaluated when conducting on-site inspections.

- Evaluate the overall effectiveness of each storm water measure and that it meets the design criteria established in the storm water pollution prevention plan. The effectiveness of erosion control measures should be evaluated based on the condition of vegetative cover or evidence of erosion. Effectiveness of sediment control measures will be based on the presence of sediment behind or within the sediment control measure. Each storm water measure should be evaluated to ensure that:

    - Each measure has been installed correctly and to the standards and specifications outlined in the storm water pollution prevention plan.
    - Each measure is functioning and/or performing properly.
    - Measures have not been damaged.
    - Each measure has not exceeded its maintenance requirements.
    - Deficient measures noted on prior inspection reports have been appropriately addressed and corrective actions taken.
    - Measures posing an off-site pollutant discharge threat are identified.

- Evaluate construction activities that may impact the implementation of the storm water pollution prevention plan. Construction and land-disturbing activities are dynamic processes. Sites subject to grading and earthmoving operations can drastically change drainage patterns and increase the size of the drainage area above a storm water management measure. If it is anticipated that the drainage area above a storm water management measure will increase significantly once construction activities begin, the measure within the watershed should be designed to accommodate the additional storm water runoff. If the increased size in the drainage area was not anticipated, it will most likely be necessary to adjust or modify the design of the existing storm water measure and/or install new or additional measures. The project manager/inspector must be cognizant of all land-disturbing activities and must be prepared to make field modifications as the situation warrants.

- Assess areas left void of protective cover. Erosion control is the most effective form of sediment control. Areas that have been brought to final grade or that will remain idle for a period of time (e.g., 15 days or more; local ordinances may be more restrictive) should be stabilized as quickly as possible. If areas can not be stabilized quickly because of weather, construction activities, or other site conditions, the project manager/inspector should be prepared to offer alternatives to address the area of concern.

- Evaluate areas that have been stabilized. Vegetative measures should be evaluated in the early stages of growth to determine the viability of the stand. Evaluate vegetation to determine if there is a need for reseeding, application of fertilizer or lime, or other maintenance items.

- Good housekeeping is another important aspect to any project. The project manager/inspector should always be aware of the other activities at the site that may generate pollutants. This includes but is not limited to chemical storage, waste disposal, concrete washout, and on-site fuel storage. An effective approach to evaluating these types of pollutants includes verifying the adequacy of trash receptacles, reviewing waste disposal practices and procedures (recycling, hazardous waste bins, etc.), reviewing spill prevention plans, and checking the use and integrity of containment systems.

Once deficiencies and issues have been identified and documented, corrective actions need to be taken to ensure the integrity of the storm water measures. Some of these actions include:

- Removal of sediment from sediment control structures.
- Replacement or repair of damaged measures.
- Repair of damaged surface stabilization measures.
- Revised or modified procedures for clean-up of spills and improper handling of project site waste.

Follow-Up and Corrective Actions

One of the most critical steps of any inspection is follow-up and implementation of corrective actions. An inspection may indicate that an existing storm water quality measure is ineffective. A measure that is ineffective or has failed requires immediate corrective action(s). Depending on the severity of the situation corrective actions may require a re-assessment of the impacted area and modification of an existing measure or selection and design of a new measure. The project manager/inspector is the best qualified individual to oversee and coordinate corrective actions. In most situations, he or she can identify who is responsible for taking actions to correct the deficiencies, provide guidance and direction in correcting the deficiency(ies), select alternative measures, and make recommendations. This individual should also be available to meet on site with the project engineer, site designer, and/or contractors to clarify documented deficiencies and resolve issues that may be associated with the required corrective actions. However, not every situation will warrant a field meeting. Often, issues can be resolved through a telephone call or e-mail.

Some corrective actions may require engineering and design. Therefore, the project manager/inspector may need to coordinate with the project engineer and or site designer to make the appropriate changes. These design changes may also require modification to the construction plans and/or storm water pollution prevention plan.

Corrective actions should be scheduled within 24 hours of an inspection. This is especially true in situations where pending storm conditions are apparent. Deficiencies should be prioritized and corrective actions planned for the most serious deficiencies first, followed by corrective actions for all areas of concern. It is very important to have routine maintenance materials and supplies available at the project site if corrective actions are to be made in a timely manner. Items and materials that should be readily available to project personnel include but are not limited to seed, mulch, and silt fence. Some structural repairs are not always easily corrected, but these types of situations should be anticipated and procedures in place for addressing the area of concern.

Inspection & Project Documentation

When conducting an inspection it is important that the project manager/inspector document his or her findings through a written inventory report or an inspection log.

Information included in the inspection report should include but is not limited to:

- The name of the project manager/inspector.
- Qualifications of the project manager/inspector (may be required by local regulating authorities).
- Date and time of the inspection.
- Weather conditions at the time of the inspection.
- A record of storm events (0.5 inches or more) that have occurred since the last inspection.
- Overall condition of the construction site.
- The condition of each storm water measure and/or area of the project.
- Identification of project areas that may require an alternative storm water quality measure(s) or installation of a measure(s) that had not been identified on the original plan.

- Required or recommended maintenance actions needed for each storm water measure.
- Actions taken to address deficiencies.
  - Recommendations for corrective action; and/or
  - Corrective action implemented to address the deficiencies.
- Maintenance and repair activities that were performed since the last inspection, who they were performed by, and the condition of the measure.
- Recommendations to amend the plan if unexpected conditions are present that require attention.
- Documentation showing who was given responsibility to address each deficiency.
- Documentation showing who received copies of the report.
- Statement of certification by the inspector that the report is accurate and true.

As the project manager/inspector evaluates a project, he or she should record all their observations. For ease of recording, site inspections can be documented using a standard inspection form or using a small tape recorder. If a tape recorder is used during the evaluation, the information should be transcribed into a written report as soon as possible after the inspection is completed.

A camera can be an invaluable tool for documenting activities and problems observed during the inspection. Digital cameras are particularly well suited for use on construction site inspections. They are small, easy to use, and can provide immediate visual documentation. Pictures should clearly show the deficiency(ies) observed and there should be a clear cross-reference between the photographs and the inspection report.

It is important that inspection logs and/or reports used on the project site meet the individual needs of the project manager/inspector and the project site owner. Reports should adequately represent the project site and should be written in a clear, concise manner. References, deficiencies, and corrective action should be recorded in adequate detail and at a level that is easily understood by project site owners, contractors, and others who need to understand the corrective actions recommended. In some situations, inspection reports may include specific standards and specifications that provide maintenance and/or installation requirements for storm water management measures.

Retention of Project Records

From the very start of a project, all reports and correspondence should be filed in a project site logbook or project file. The purpose of a logbook or project file is to maintain a written record of all correspondence, telephone logs, site inspections, corrective actions and other documents related to the project. Project logbooks or project files should also include all correspondence and inspection reports received from the local regulatory authority, including all corrective actions taken in response to deficiencies noted on the local regulatory authority's on-site inspection reports. A well-maintained logbook or project file will serve as a record of performance and compliance with the storm water pollution prevention plan and local, state, or federal regulations applicable to the project.

It is recommended that all project site records be maintained for a minimum of three years following termination of the project, unless specified otherwise by a regulatory requirement or legal counsel. On some projects it may be necessary to maintain project site records for longer periods of time, especially if there is a pending enforcement or legal action against the project.

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PROJECT CLOSURE

Project closure is the culmination of construction activities and the final step associated with a project. As construction activities are brought to a close it is important to verify that the project has been built as designed and that any outstanding issues are resolved prior to equipment being removed from the project site.

One of the first steps in the project closure process is to review all project documentation, including project logs and inspection reports, to ensure that all requirements, conditions, and specifications have been met. If there are any outstanding issues, they should be addressed and appropriate actions or measures taken.

In addition to reviewing project documentation, project representatives should make a field assessment of the project and develop and implement a final closure plan for the project site. The field assessment should include the following:

- An assessment of the overall condition of the project, including but not limited to density of vegetation, proper disposal of all accumulated waste and debris, and removal of accumulated sediment.
- All storm water management systems (e.g., storm sewer systems) should be in working order.
- All storm water measures that will remain as permanent features at the site should be evaluated to ensure that they will function according to design standards. This may require the removal of sediment and other debris from the system.
- Any measures that were modified to treat runoff during construction should be returned to the original design specifications so that they function to meet the objectives of post-construction treatment.
- Once construction and all land-disturbing activities have been completed and the area has been stabilized, remove all temporary erosion and sediment control measures in a manner that minimizes land disturbance. Areas left void of protective cover due to the removal of a measure should be stabilized immediately.

The process used to verify a site is properly closed is primarily left to the project site owner and/or their representatives. One option is to hold a closeout meeting at the site with key individuals that have been involved with the project. Attendance at this meeting should include but is not limited to the owner of the project, design engineer, contractors, local planning, staff, and regulatory inspectors.

While the overall purpose of project closure is to ensure that all construction activities are complete, areas are stable, and everything is in working condition, there may also be regulatory requirements that need to be met. Regulatory agencies may require an on-site inspection to ensure that permit conditions have been met before they sign off on a project. If a final inspection is required, it is important that all regulatory requirements be fulfilled prior to scheduling the inspection.

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7

Storm Water Quality Measures: Construction & Land-Disturbing Activities

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INTRODUCTION TO STORM WATER QUALITY MEASURES: CONSTRUCTION & LAND-DISTURBING ACTIVITIES

As an area undergoes land use changes it generally requires storm water control measures to prevent or at the very least minimize the introduction of pollutants into storm water runoff. This is true for both construction and post-construction phases of a project. Sediment is the most common pollutant associated with storm water runoff from construction sites. In fact, it has been shown that sediment is the number one pollutant, by volume, of surface waters of the United States. Sediment is also the primary pollutant that is addressed by state and local officials when they regulate construction projects. However, there are several other pollutants associated with construction activities. Some of these pollutants include but are not limited to solid wastes, nutrients, pesticides, petroleum products, and chemicals. This section of the manual lists several storm water quality measures that have been designed to control erosion and prevent or minimize the introduction of sediment into storm water runoff and surface waters.

Construction projects generally require a variety of storm water quality measures to properly manage and minimize the introduction of pollutants into surface water runoff. It is important to note that as a project moves through the various stages of construction, it will be necessary to modify, change, and properly maintain existing storm water quality measures as well as install new measures. The storm water quality measures in this section of the manual have been grouped into categories which attempt to address particular areas of concern on an active construction site.

It is important to recognize that selecting specific storm water quality measures will require thorough site assessment and design. Many of the measures can be applied and/or installed based on general criteria. However, there are measures contained within this manual that will require selection and design that is based on sound engineering principles. These measures include but are not limited to sediment basins, grassed and riprap-lined channels. These measures should be evaluated for feasibility and designed by a qualified individual. All structural measures should be designed by a professional engineer.

Some of the measures illustrated in Chapter 7 are only a representation of storm water quality/runoff control measures. Other alternatives may be available through design, field modification, or commercially available products.

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SITE ACCESS & PREPARATION

Prior to initiating land-disturbing activities on any construction site, it is important to properly prepare the site to minimize the potential for erosion and off-site sedimentation, preserve valuable vegetation, and protect unique/sensitive areas. This section of the manual contains measures that should be implemented on a construction site prior to initiating any land disturbance. It is also important to understand that every site is unique and has its own set of challenges. Therefore, not all measures contained in this section will be applicable to every site. Measures should be chosen to fit the project's specific site conditions.

Another important point to remember is that in most cases use of a single measure will not be sufficient to control erosion and sedimentation throughout all stages of construction activity. Therefore, measures included in other sections of this manual will need to be implemented during the site preparation phase. In particular, perimeter sediment control measures should be installed downstream of all proposed land-disturbing activities before actual disturbance begins in each area. Again, measures should be chosen to fit the project's specific site conditions. For example, on some sites perimeter measures may be as simple as leaving grassy vegetation in place to act as a filter strip. Other sites may require the use of properly installed silt fence. When more severe conditions are encountered it may be necessary to use temporary or permanent diversions to divert surface water runoff to temporary sediment traps and temporary sediment basins where the sediment-laden water can be treated.

Most measures illustrated in this section are associated with proper site management. Two measures within this section specifically address construction vehicle ingress and egress. It should be noted that there are products available commercially that, when installed according to the manufacturer's specifications, perform well and are designed to reduce vehicle tracking. These products include, but are not limited to, interlocking modules or plates and specially designed high-strength double walled fabric.

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Preservation & Utilization of Existing Cover

*Refer to **Preservation & Protection – Natural Site Design** on page 5 of Chapter 4, Planning Principles & Design Considerations.*

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Clearing & Grubbing

To be released at a later time

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Tree Preservation & Protection

***Tree preservation and protection** methods are used to preserve and protect desirable trees from damage during project development.*

Purpose

To protect and insure survival of desirable existing trees from the effects of construction activities.

Specifications

Tree Selection and Planning

- Gather information from soil and topographic maps, aerial photos, and professional foresters to better understand the site, desirable trees, and how to save them.
- Walk the site to map out potential specimen trees, special features, and sensitive areas.
- Clearly identify and delineate on the construction plans all trees to be protected.
- Plan roads, sidewalks, and other infrastructure to save specimen trees and green space areas.
- Plan underground utilities so they can be combined in the same trench away from trees and potential planting sites. (If near trees, tunnel under the roots.)

Tree Protection

- Protect trees from equipment damage. (Wounds provide entry for insects and disease and reduce transport of sap.)
- If trees are damaged, repair immediately. (Repair of wounded areas allows trees to heal quickly, thus reducing insect and disease problems.)

Materials

- Fencing (orange safety fencing for increased visibility), snow fence and support posts.
- Signage.
- Wood mulch, chips, etc.
- Specialized equipment (brush cutter, rotary axe, hand tools).

Application

Tree Protection

1. Walk the site with plan and site map to verify location of specimen trees, special features, and sensitive areas.
2. If necessary, adjust the planned layout of roads, sidewalks, utilities, etc. to save specimen trees and green space areas.
3. Flag or mark all trees to be protected. Designate trees having high aesthetic value based on condition, spacing, and species. (More desirable species include beech, dogwood, sweetgum, sycamore, sugar maple, locust, hawthorn, oak, and hackberry. Less desirable species include aspen, elm, cherry, silver maple, willow, box elder, sassafras, cottonwood, and poplar.)
4. Mark for removal all undesirable or hazardous trees in the construction area. Thinning a stand ahead of time lets the remaining trees adjust to a more open environment.
5. If underground utilities must pass near or under tree rooting systems, tunnel under the roots.
6. Create traffic patterns to keep soil compaction to a minimum. (Compaction reduces the amount of air and water available to tree roots.)
7. Consider planting and/or transplanting. Small trees of desirable species can sometimes be transplanted from areas to be cleared. Property buffers, windbreaks, or green space areas can be economically established with these trees.

Avoid Compaction

1. Install fencing around a specimen tree(s) as far out as its crown to keep equipment off the rooting area.
2. If a fence cannot be erected, cushion the rooting area with six inches of wood chips, wood, or brick paths.
3. Create traffic patterns to keep soil compaction to a minimum.
4. Store supplies and equipment away from specimen tree areas.
5. Designate sites well away from trees for burning debris and washing out concrete trucks.

Reduce Damage from Grading

1. When clearing, use equipment such as a brush cutter or rotary axe, or cut by hand.
2. Where root areas must be graded, cut large roots instead of tearing them with equipment.
3. Minimize changes in the drainage pattern. (Existing trees are acclimated to the current pattern; creating a new one could injure them.)
4. Where applicable, construct retaining walls to minimize root damage from grading operations. Removal or disturbance of soil may damage the root system of the tree.
5. Avoid putting fill over the root system. Adding soil material reduces water and air availability required for the root system and tree.

Avoid Wounding Trees

1. Protect trees from equipment damage by creating some type of barrier, fencing them off, or wrapping individual trees with snow fencing.
2. Prune low-hanging limbs that could otherwise be broken off by equipment.
3. Where feasible, leave trees in groups. Trees growing in wooded areas are used to shade from the surrounding trees, so when they are suddenly exposed to open areas they become susceptible to sun scald, frost cracks, excessive branching, and wind throw.

Repair Tree Damage

(Utilize the services of a consulting forester)

1. Properly prune all damaged limbs. Avoid leaving stubs.
2. Aerate soil where compaction has been excessive.
3. Fertilize to improve tree growth, vigor, and appearance.
4. Water during dry periods to help offset soil compaction and root damage.

Maintenance

- Inspect at least once every seven calendar days.
- Repair perimeter barriers if damaged.
- Inspect for damage from construction equipment, etc. Repair wounds simply by removing damaged bark and wood tissue. **Do not use tree paint.**
- Cable and brace any trunk splits, weak forks, and large limbs.

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Temporary Construction Ingress/Egress Pad (Large Sites—Two Acres or Larger)

*A **temporary construction ingress/egress pad** is a sediment control measure consisting of a stabilized aggregate pad with geotextile underlayment that is used at any point where construction traffic will be traversing between a large construction site and adjoining public right-of-way, street, alley, sidewalk, or parking areas.*

Purpose

To provide ingress/egress to a construction site and minimize tracking of mud and sediment onto public roadways.

Specifications

Location

- Avoid locating on steep slopes or at curves in public roads.

Dimensions

- Width – 20 feet minimum or full width of entrance/exit roadway, whichever is greater.
- Length – 150 feet minimum (length can be shorter for small sites).
- Thickness – eight inches minimum.

Washing Facility (optional)

- Level area with three inch, or larger, washed aggregate or install a commercial wash rack.
- Divert waste water to a sediment trap or basin.

Materials

- One to two and one-half inch diameter washed aggregate [Indiana Department of Transportation Course Aggregate No. 2 (see Appendix D)].
- One-half to one and one-half inch diameter washed aggregate [INDOT CA No. 53 (see Appendix D)].
- Geotextile fabric underlayment (see Appendix C) (used as a separation layer to prevent intermixing of aggregate and the underlying soil material and to provide greater bearing strength when encountering wet conditions or soils with a seasonal high water table limitation).

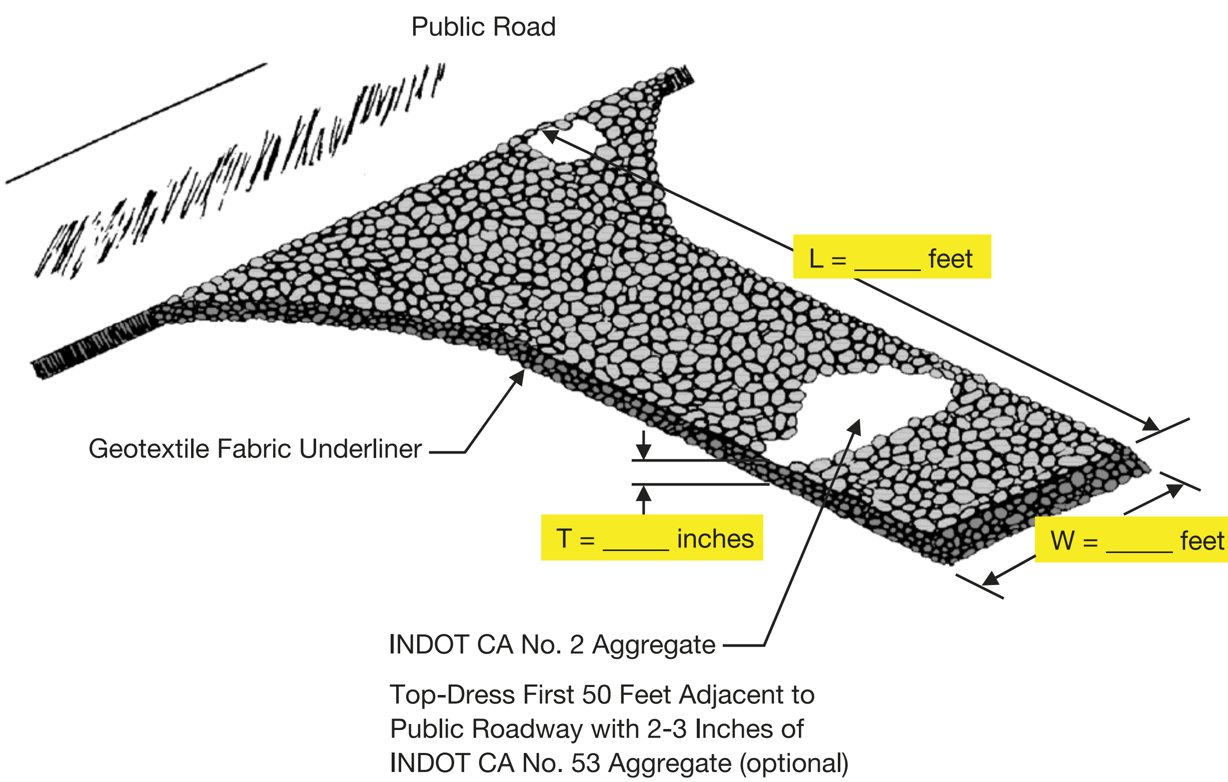
Installation

1. Remove all vegetation and other objectionable material from the foundation area.
2. Grade foundation and crown for positive drainage. If the slope of the construction entrance is toward a public road and exceeds two percent, construct an eight inch high diversion ridge with a ratio of 3-to-1 side slopes across the foundation area about 15 feet from the entrance to divert runoff away from the road (see Temporary Construction Ingress/Egress Pad Cross-Section View Worksheet).
3. Install a culvert pipe under the pad if needed to maintain proper public road drainage.
4. If wet conditions are anticipated, place geotextile fabric on the graded foundation to improve stability.
5. Place aggregate (INDOT CA No. 2) to the dimensions and grade shown in the construction plans, leaving the surface smooth and sloped for drainage.
6. Top-dress the first 50 feet adjacent to the public roadway with two to three inches of washed aggregate (INDOT CA No. 53) [optional, used primarily where the purpose of the pad is to keep soil from adhering to vehicle tires].
7. Where possible, divert all storm water runoff and drainage from the ingress/egress pad to a sediment trap or basin.

Maintenance

- Inspect daily.
- Reshape pad as needed for drainage and runoff control.
- Top dress with clean aggregate as needed.
- Immediately remove mud and sediment tracked or washed onto public roads.
- Flushing should only be used if the water can be conveyed into a sediment trap or basin.

Temporary Construction Ingress/Egress Pad Plan View Worksheet (large sites—two acres or larger)

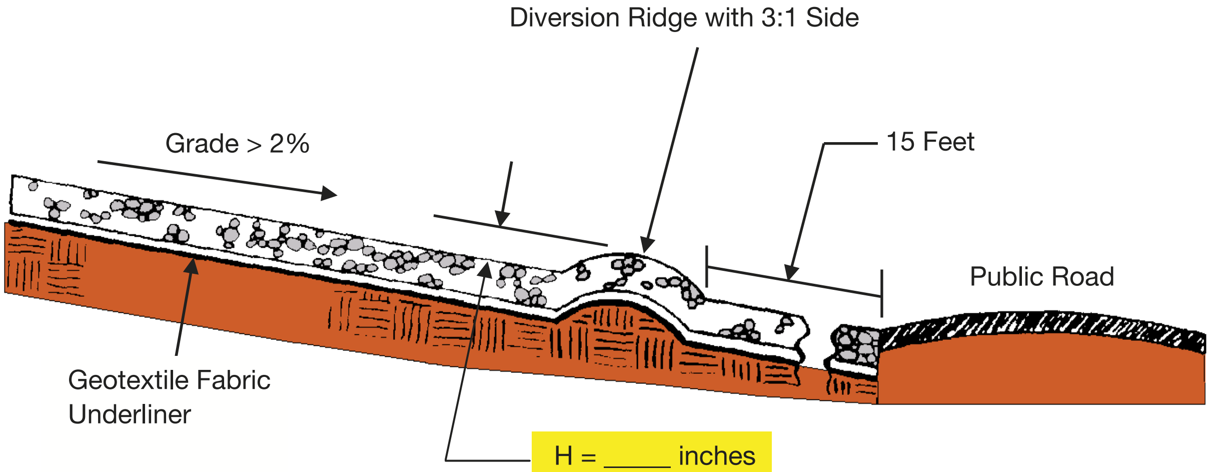


L = Ingress/Egress Pad Length
W = Ingress/Egress Pad Width
T = Aggregate Thickness

(Note: For minimum dimensions, see the "Specifications" section of this measure.)

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

Temporary Construction Ingress/Egress Pad Cross-Section View Worksheet (large sites two acres or larger)



H = Height of Diversion Ridge

(*Note: 8 inches minimum*)

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

Temporary Construction Ingress/Egress Pad (Small Sites—Less Than Two Acres)

*A **temporary construction ingress/egress pad** is a sediment control measure, consisting of a stabilized aggregate pad with geotextile underlayment, used at any point where construction traffic will be traversing between a small construction site and the adjoining public right-of-way or street.*

Purpose

- To provide stable entrance/exit conditions from an individual lot or building site.
- To keep mud and sediment off of public roadways.

Specifications

Location

- Avoid locating on steep slopes or at curves in public roads.

Dimensions

- Width – 12 feet minimum or full width of entrance/exit drive, whichever is greater.
- Length – 50 feet minimum or full length of drive, whichever is greater.
- Thickness – six inches minimum.

Materials

- One to two and one-half inch diameter washed aggregate [INDOT CA No. 2 (see Appendix D)].
- One-half to one and one-half inch washed aggregate [INDOT CA No. 53 (see Appendix D); optional, used primarily where the purpose of the pad is to keep soil from adhering to vehicle tires].

- Geotextile fabric underlayment (see Appendix C) (used as a separation layer to prevent intermixing of aggregate and the underlying soil material and to provide greater bearing strength when encountering wet conditions or soils with a seasonal high water table limitation).

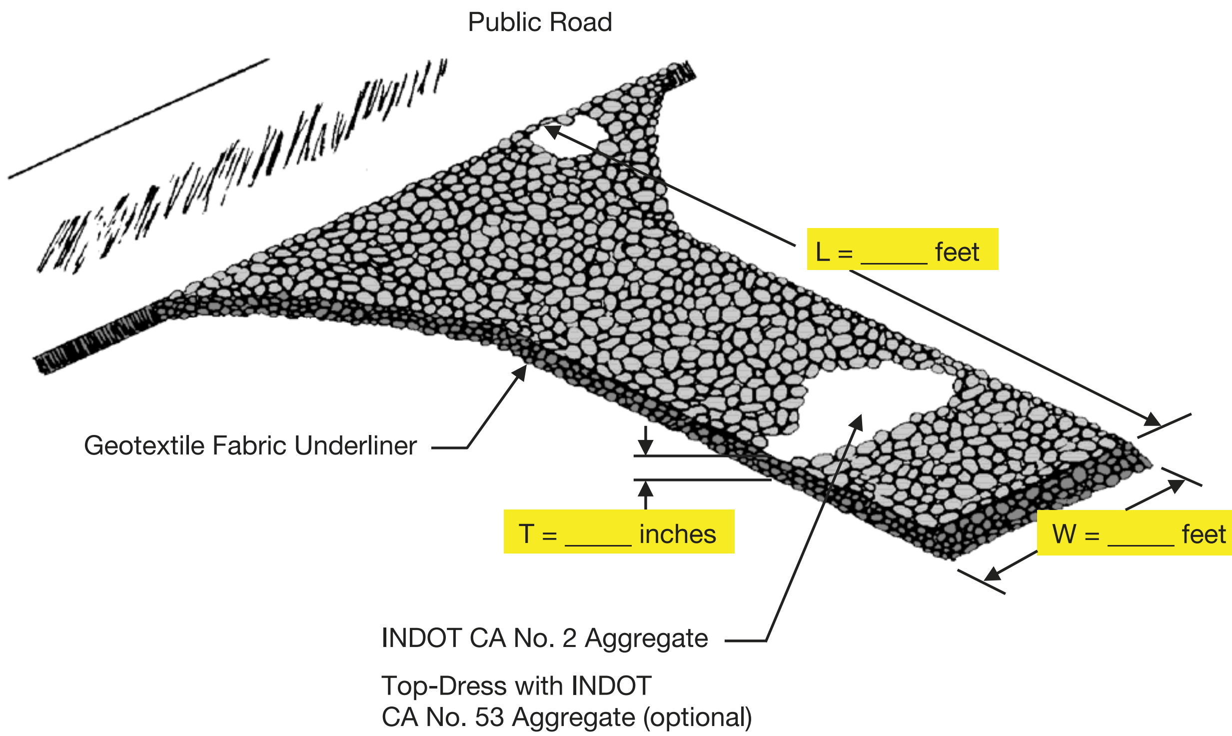
Installation

1. Remove all vegetation and other objectionable material from the foundation area.
2. Grade the foundation and crown for positive drainage.
3. Install a culvert pipe under the pad if needed to maintain proper public road drainage.
4. If wet conditions are anticipated, place geotextile fabric on the graded foundation to improve stability.
5. Place aggregate (INDOT CA No. 2) to the dimensions and grade shown in the construction plans, leaving the surface smooth and sloped for drainage.
6. Top-dress the drive with washed aggregate (INDOT CA No.53).
7. Where possible, divert all storm water runoff and drainage from the temporary construction ingress/egress pad to a sediment trap or basin.

Maintenance

- Inspect daily.
- Reshape pad as needed for drainage and runoff control.
- Top-dress with clean aggregate as needed.
- Immediately remove mud and sediment tracked or washed onto public roads.
- Flushing should only be used if the water from the construction drive can be conveyed into a sediment trap or basin.

Temporary Construction Ingress/Egress Pad
Plan View Worksheet
(small sites less than two acres)



L = Ingress/Egress Pad Length

W = Ingress/Egress Pad Width

T = Aggregate Thickness

(Note: For minimum dimensions, see the "Specifications" section of this measure.)

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

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Topsoil Salvage & Utilization

***Topsoil salvage and utilization** involves the preservation and use of topsoil to enhance final site stabilization with vegetation.*

Purpose

- To provide a method of preserving topsoil for use in establishing vegetation to achieve final site stabilization.
- 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.

Specifications

Material

Typically the darker, friable, loamy surface layer of soil found immediately below vegetation. (Topsoil is the surface layer of the soil profile, generally characterized as darker than the underlying subsoil due to enrichment with organic matter. It is the major zone of root development and biological activity. Microorganisms that enhance plant growth thrive in this layer. Topsoil can usually be differentiated from subsoil by texture as well as color. Clay content usually increases in the subsoil. The depth of natural topsoil may be quite variable. On severely eroded sites it may be gone entirely.)

Storage Area

- Free of stumps, rock, and construction debris.
- Stockpile covered with vegetation or a tarp.
- Surrounded by a sediment barrier or sediment filter.
- Stockpile outside rooting zone of trees to be protected.

Removal/Storage/Respreading Plan

Needed to assure these operations will be compatible with overall construction activities at the site.

Application

Salvaging and Stockpiling Topsoil

1. Determine depth and suitability of topsoil at site. For help, contact your local soil and water conservation district office to obtain a county soil survey report or utilize the services of a consulting soil scientist.
2. Prior to stripping topsoil, install any site-specific down slope measures needed to control storm water runoff and sedimentation.
3. Remove soil material no deeper than the "surface soil" (e.g., A or Ap horizon).
4. Stockpile the material in accessible locations that will not interfere with other construction activities or block drainage. Several small stockpiles around the construction site are usually more efficient and easier to contain than one large stockpile.
5. Stockpiled soil should be temporarily seeded or covered with a tarp and/or surrounded by a sediment control measure.

Spreading Topsoil

1. Prior to applying topsoil, grade the subsoil and roughen the top three to four inches by disking. (This helps the topsoil bond with the subsoil. If the topsoil and existing soil surface are not properly bonded, water will not infiltrate evenly and it will be difficult to establish vegetation.)
2. Apply topsoil evenly to a depth of at least four inches, then compact slightly to improve contact with the subsoil.
    a. Depths of four inches or greater are recommended if the underlying material is bedrock, fine-textured clayey soils, loose sand, rock fragments, aggregate, or other unsuitable soil material.
    b. Do not apply topsoil when the site is wet, muddy, or frozen because it makes spreading difficult, inhibits bonding, can cause compaction problems, and forms a cloddy seedbed. Whenever possible avoid applying topsoil to the existing soil surface if the two layers have contrasting textures. Clayey topsoil over sandy subsoil is a particularly poor combination, as water creeps along the junction between the two soil layers and may cause the topsoil to slough.

c. Applying topsoil on slopes with a ratio of 2:1 or greater may result in soil slippage and may require additional measures to provide good bonding of the soil material.

3. After spreading the topsoil, grade and stabilize the site.

Maintenance

- Inspect daily.
- Check for damage to perimeter barrier; repair immediately.
- Check for erosion or damage to newly spread topsoil; repair immediately and revegetate.

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SURFACE STABILIZATION

Surface stabilization is one of the most important principles of erosion and sediment control. Reducing erosion at the source is much more effective and efficient than trying to trap suspended sediment in surface water runoff. Therefore, the measures contained in this section are probably the most important management measures in the manual.

Minimizing the amount of land disturbance and length of time unvegetated areas are exposed to erosive forces can greatly reduce the potential for erosion and off-site sediment damage. Temporary seeding and/or mulching of even relatively small, idle, disturbed areas can make a significant difference in the quantity of suspended sediment. This reduction in sediment load can have a profound effect on the frequency and expense of maintenance operations.

The surface stabilization measures listed in this section of the manual have been designed to facilitate vegetative establishment on unvegetated areas or provide a soil cover that will minimize the exposure of soil to the erosive forces of wind and water. It is important to note that these measures require frequent monitoring and maintenance to ensure that the soil surface is adequately protected.

Surface stabilization will typically not require detailed site investigations and design. However, the stabilization of steep slopes and conveyance systems, and the utilization of materials such as riprap, will require site assessment and the application of sound engineering principles. A professional experienced in structural design may need to be consulted in these situations.

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Temporary Seeding

Temporary seeding *involves the establishment of rapid growing annual grasses or small grains to stabilize disturbed areas until such time as a permanent, nonerosive cover can be established.*

Purpose

- To provide vegetative cover where permanent seeding is not desirable or practical.
- To reduce erosion and sedimentation damage by stabilizing disturbed areas.
- To reduce problems associated with mud or dust from unvegetated soil surfaces during construction.
- To reduce sediment-laden storm water runoff from being transported to downstream areas.
- To improve visual aesthetics of construction areas.

Specifications

Seedbed Preparation

Grade and apply soil amendments.

Seeding Frequency

Seed rough graded areas daily while soil is still loose and moist.

Density of Vegetative Cover

Eighty percent or greater over the soil surface.

Materials

- Soil Amendments – Select materials and rates as determined by a soil test (contact your county soil and water conservation district or cooperative extension office for assistance and soil information, including available soil testing services) or 400 to 600 pounds of 12-12-12 analysis fertilizer, or equivalent. Consider the use of reduced phosphorus application where soil tests indicate adequate phosphorous levels in the soil profile.
- Seed – Select appropriate plant species seed or seed mixtures on the basis of quick germination, growth, and time of year to be seeded (see Table 1).
- Mulch –
  - Straw, hay, wood fiber, etc. (to protect seedbed, retain moisture, and encourage plant growth).
  - Anchored to prevent removal by wind or water or covered with manufactured erosion control blankets.

Table 1. Temporary Seeding Specifications

Seed Species[1]	Rate per Acre	Planting Depth	Optimum Dates[2]
Wheat or Rye	150 lbs.	1 to 1½ inches	Sept. 15 – Oct. 30
Spring Oats	100 lbs.	1 inch	March 1 – April 15
Annual Ryegrass	40 lbs.	¼ inch	March 1 – May 1 Aug. 1 – Sept. 1
German Millet	40 lbs.	1 to 2 inches	May 1 – June 1
Sudangrass	35 lbs.	1 to 2 inches	May 1 – July 30
Buckwheat	60 lbs.	1 to 2 inches	April 15 – June 1
Corn (*broadcast*)	300 lbs.	1 to 2 inches	May 11 – Aug. 10
Sorghum	35 lbs.	1 to 2 inches	May 1 – July 15

[1] Perennial species may be used as a temporary cover, especially if the area to be seeded will remain idle for more than one year (see **Permanent Seeding** on page 35).

[2] Seeding done outside the optimum seeding dates increases the chances of seeding failure. Dates may be extended or shortened based on the location of the project site within the state.

Notes:

Mulch alone is an acceptable temporary cover and may be used in lieu of temporary seeding, provided that it is appropriately anchored.

A high potential for fertilizer, seed, and mulch to wash exists on steep banks, cuts, and in channels and areas of concentrated flow.

Application

Seedbed Preparation

1. Test soil to determine pH and nutrient levels.
2. Apply soil amendments as recommended by the soil test. If testing is not done, apply 400 to 600 pounds per acre of 12-12-12 analysis fertilizer, or equivalent.
3. Work the soil amendments into the upper two to four inches of the soil with a disk or rake operated across the slope.

Seeding

1. Select a seed species or an appropriate seed mixture and application rate from Table 1.
2. Apply seed uniformly with a drill or cultipacker seeder or by broadcasting. Plant or cover seed to the depth shown in Table 1.

   Notes:
   1. If drilling or broadcasting the seed, ensure good seed-to-soil contact by firming the seedbed with a roller or cultipacker after completing seeding operations.
   2. Daily seeding when the soil is moist is usually most effective.
   3. If seeding is done with a hydroseeder, fertilizer and mulch can be applied with the seed in a slurry mixture.

3. Apply mulch (see **Mulching** on page 55 or **Compost Mulching** on page 59) and anchor it in place.

Maintenance

- Inspect within 24 hours of each rain event and at least once every seven calendar days.
- Check for erosion or movement of mulch and repair immediately.
- Monitor for erosion damage and adequate cover (80 percent density); reseed, fertilize, and apply mulch where necessary.
- If nitrogen deficiency is apparent, top-dress fall seeded wheat or rye seeding with 50 pounds per acre of nitrogen in February or March.

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Permanent Seeding

***Permanent seeding** involves the establishment of a permanent vegetative cover to protect soils from erosive forces.*

Purpose

- To provide permanent vegetative cover and improve visual aesthetics of a project site.
- To reduce erosion and sedimentation damage by stabilizing disturbed areas.
- To reduce problems associated with mud or dust from unvegetated soil surfaces.
- To reduce sediment-laden storm water runoff from being transported to downstream areas.

Specifications

Seedbed Preparation

Grade and apply soil amendments.

Seeding Frequency

Seed final graded areas daily while soil is still loose and moist.

Density of Vegetative Cover

Ninety percent or greater over the soil surface.

Materials

- Soil Amendments – Select materials and rates as determined by a soil test (contact your county soil and water conservation district or cooperative extension office for assistance and soil information, including available soil testing services) or 400 to 600 pounds of 12-12-12 analysis fertilizer, or equivalent. Consider the use of reduced phosphorus application where soil tests indicate adequate phosphorous levels in the soil profile.
- Seed – Select an appropriate plant species seed or seed mixture on the basis of soil type, soil pH, region of the state, time of year, and intended land use of the area to be seeded (see Table 1).
- Mulch –
    - Straw, hay, wood fiber, etc. (to protect seedbed, retain moisture, and encourage plant growth).
    - Anchored to prevent removal by wind or water or covered with premanufactured erosion control blankets.

Application

Site Preparation

1. Grade the site to achieve positive drainage.
2. Add topsoil (see **Topsoil Salvage and Utilization** on page 25) or compost mulch (see **Compost Mulching** on page 59) to achieve needed depth for establishment of vegetation. (Compost material may be added to improve soil moisture holding capacity, soil friability, and nutrient availability.)

Seedbed Preparation

1. Test soil to determine pH and nutrient levels.
2. Apply soil amendments as recommended by the soil test and work into the upper two to four inches of soil. If testing is not done, apply 400 to 600 pounds per acre of 12-12-12 analysis fertilizer, or equivalent.
3. Till the soil to obtain a uniform seedbed. Use a disk or rake, operated across the slope, to work the soil amendments into the upper two to four inches of the soil.

Seeding

Optimum seeding dates are March 1 to May 10 and August 10 to September 30. Permanent seeding done between May 10 and August 10 may need to be irrigated. Seeding outside or beyond optimum seeding dates is still possible with the understanding that reseeding or overseeding may be required if adequate surface cover is not achieved. Reseeding or overseeding can be easily accomplished if the soil surface remains well protected with mulch.

1. Select a seeding mixture and rate from Table 1. Select seed mixture based on site conditions, soil pH, intended land use, and expected level of maintenance.
2. Apply seed uniformly with a drill or cultipacker seeder (see Figure 1) or by broadcasting (see Figure 2). Plant or cover the seed to a depth of one-fourth to one-half inch. If drilling or broadcasting the seed, ensure good seed-to-soil contact by firming the seedbed with a roller or cultipacker after completing seeding operations. (If seeding is done with a hydroseeder (see Figure 3), fertilizer and mulch can be applied with the seed in a slurry mixture.)
3. Mulch all seeded areas (see **Mulching** on page 55 and **Compost Mulching** on page 59) and use appropriate methods to anchor the mulch in place. Consider using erosion control blankets on sloping areas and conveyance channels (see **Erosion Control Blanket** on page 63).

Maintenance

- Inspect within 24 hours of each rain event and at least once every seven calendar days until the vegetation is successfully established.
- Characteristics of a successful stand include vigorous dark green or bluish-green seedlings with a uniform vegetative cover density of 90 percent or more.
- Check for erosion or movement of mulch.
- Repair damaged, bare, gullied, or sparsely vegetated areas and then fertilize, reseed, and apply and anchor mulch.
- If plant cover is sparse or patchy, evaluate the plant materials chosen, soil fertility, moisture condition, and mulch application; repair affected areas either by overseeding or preparing a new seedbed and reseeding. Apply and anchor mulch on the newly seeded areas.
- If vegetation fails to grow, consider soil testing to determine soil pH or nutrient deficiency problems. (Contact your soil and water conservation district or cooperative extension office for assistance.)
- If additional fertilization is needed to get a satisfactory stand, do so according to soil test recommendations.
- Add fertilizer the following growing season. Fertilize according to soil test recommendations.
- Fertilize turf areas annually. Apply fertilizer in a split application. For cool-season grasses, apply one-half of the fertilizer in late spring and one-half in early fall. For warm-season grasses, apply one-third in early spring, one-third in late spring, and the remaining one-third in middle summer.

Table 1. Permanent Seeding Recommendations

This table provides several seed mixture options. Additional seed mixtures are available commercially. When selecting a mixture, consider intended land use and site conditions, including soil properties (e.g., soil pH and drainage), slope aspect, and the tolerance of each species to shade and drought.

Open Low-Maintenance Areas
(remaining idle more than six months)

Seed Mixtures	Rate per Acre Pure Live Seed	Optimum Soil pH
1. Perennial ryegrass - white clover[1]	70 lbs. 2 lbs.	5.6 to 7.0
2. Perennial ryegrass - tall fescue[2]	70 lbs. 50 lbs.	5.6 to 7.0
3. Tall fescue[2] - white clover[1]	70 lbs. 2 lbs.	5.5 to 7.5

Steep Banks and Cuts, Low-Maintenance Areas (not mowed)

Seed Mixtures	Rate per Acre Pure Live Seed	Optimum Soil pH
1. Smooth brome grass - red clover[1]	35 lbs. 20 lbs.	5.5 to 7.0
2. Tall fescue[2] - white clover[1]	50 lbs. 2 lbs.	5.5 to 7.5
3. Tall fescue[2] - red clover[1]	50 lbs. 20 lbs.	5.5 to 7.5
4. Orchard grass - red clover[1] - white clover[1]	30 lbs. 20 lbs. 2 lbs.	5.6 to 7.0
5. Crownvetch[1] - tall fescue[2]	12 lbs. 30 lbs.	5.6 to 7.0

Lawns and High-Maintenance Areas

Seed Mixtures	Rate per Acre Pure Live Seed	Optimum Soil pH
1. Bluegrass	140 lbs.	5.5 to 7.0
2. Perennial ryegrass (turf type)	60 lbs. 90 lbs.	5.6 to 7.0
3. Tall fescue (turf type)[2] - bluegrass	170 lbs. 30 lbs.	5.6 to 7.5

Channels and Areas of Concentrated Flow

Seed Mixtures	Rate per Acre Pure Live Seed	Optimum Soil pH
1. Perennial ryegrass - white[1]	150 lbs. 2 lbs.	5.5 to 7.0
2. Kentucky bluegrass - smooth bromegrass - switchgrass - timothy - perennial ryegrass - white clover [2]	20 lbs. 10 lbs. 3 lbs. 4 lbs. 10 lbs. 2 lbs.	5.5 to 7.5
3. Tall fescue[1] - white clover [2]	150 lbs. 2 lbs.	5.5 to 7.5
4. Tall fescue[2] - perennial ryegrass - Kentucky bluegrass	150 lbs. 20 lbs. 20 lbs.	5.5 to 7.5

[1] 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 (see **Dormant Seeding and Frost Seeding** on page 41); and (c) if legumes are fall-seeded, do so in early fall.

[2] Tall fescue provides little cover for, and may be toxic to some species of wildlife. The Indiana Department of Natural Resources recognizes the need for additional research on alternatives 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.

Notes:

1. An oat or wheat companion or nurse crop may be used with any of the above permanent seeding mixtures, at the following rates:

    (a) spring oats – one-fourth to three-fourths bushel per acre
    (b) wheat – no more than one-half bushel per acre

2. A high potential for fertilizer, seed, and mulch to wash exists on steep banks, cuts, and in channels and areas of concentrated flow.

Figure 1: Cultipacker Seeder

Figure 2: Broadcast Seeding

Figure 3: Hydroseeding

Dormant Seeding & 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 late winter when soils are in the freeze-thaw stage. (This measure can be used to repair or enhance areas having thin or declining vegetative cover or to revegetate an area.)*

Purpose

- To provide early germination and soil stabilization in the spring.
- To reduce sediment-laden storm water runoff from being transported to downstream areas.
- To improve the visual aesthetics of the construction area.
- To repair or enhance previous seeding.

Specifications

Seedbed Preparation

Grade and apply soil amendments as recommended by a soil test (incorporate soil amendments into soil prior to soil freezing).

Density of Vegetative Cover

Eighty percent or greater over the soil surface.

Materials

- Soil Amendments – Select materials and rates as determined by a soil test (contact your county soil and water conservation district or cooperative extension office for assistance and soil information, including available soil testing services) or 200 to 300 pounds of 12-12-12 analysis fertilizer, or equivalent. Consider the use of reduced phosphorus application where soil tests indicate adequate phosphorous levels in the soil profile.

- Seed – Select an appropriate plant species seed or seed mixture on the basis of soil type, soil pH, region of the state, time of year, and intended land use of the area to be seeded (see Table 1 or Table 2).
- Mulch –
  - Straw, hay, wood fiber, compost, etc. (to protect seedbed, retain moisture, and encourage plant growth).
  - Anchored to prevent removal by wind or water or covered with premanufactured erosion control blankets.

Application

(see Tables 1 and 2)

Site Preparation

1. Grade the site to achieve positive drainage.
2. Add topsoil (see **Topsoil Salvage and Utilization** on page 25) to achieve needed depth for establishment of vegetation.

Dormant Seeding

Site preparation, 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.

1. Test soil to determine pH and nutrient levels.
2. Broadcast soil amendments as recommended by a soil test and work into the upper two to four inches of soil. If testing was not done, apply 200 to 300 pounds per acre of 12-12-12 analysis fertilizer, or equivalent.
3. Apply and anchor mulch (see **Mulching** on page 55 and **Compost Mulching** on page 59) immediately after completion of grading and addition of soil amendments.
4. Select an appropriate seed species or mixture from Table 1 for temporary seeding or Table 2 for permanent seeding. Broadcast the seed on top of the mulch and/or into existing ground cover at the rate shown. (Seed areas when soil temperatures are below 50^{o} F but the soil is not frozen.)

Frost Seeding

Seed is broadcast over the prepared seedbed and incorporated into the soil by natural freeze-thaw action.

1. Test soil to determine pH and nutrient levels.

2. Broadcast soil amendments as recommended by a soil test and work into the upper two to four inches of soil before it freezes. If testing was not done, apply 200 to 300 pounds per acre of 12-12-12 analysis fertilizer, or equivalent.
3. Select an appropriate seed species or mixture from Table 1 for temporary seeding or Table 2 for permanent seeding. Broadcast the seed on the seedbed or into the existing ground cover at the rate shown. (Seed areas when the soil is frozen. Do not work the seed into the soil.)

Maintenance

- Inspect at least once every seven calendar days.
- Check for erosion or movement of mulch.
- Check for inadequate cover (less than 80 percent density over the soil surface); reseed and mulch in mid to late April if necessary. For best results, reseed within the recommended dates shown in Temporary Seeding on page 31 and Permanent Seeding on page 35.
- Apply 200 to 300 pounds per acre of 12-12-12 analysis fertilizer, or equivalent, between April 15 and May 10 or during periods of vigorous growth.
- Fertilize turf areas annually. Apply fertilizer in a split application. For cool-season grasses, apply one-half of the fertilizer in late spring and one-half in early fall. For warm-season grasses, apply one-third in early spring, one-third in late spring, and the remaining one-third in middle summer.

Table 1. Temporary Dormant or Frost Seeding Recommendations

Seed Species	Rate per Acre
Wheat or rye	150 lbs.
Spring oats	150 lbs.
Annual ryegrass	60 lbs.

Table 2 provides several seeding options. Additional seed 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 drought.

Table 2. Permanent Dormant or Frost Seeding Recommendations

Open Low-Maintenance Areas (remaining idle more than six months)

Seed Mixtures	Rate per Acre Pure Live Seed	Optimum Soil pH
1. Perennial ryegrass - white clover[1]	75 lbs. 3 lbs.	5.6 to 7.0
2. Kentucky bluegrass - smooth bromegrass - switchgrass - timothy - perennial ryegrass - white clover[1]	30 lbs. 15 lbs. 5 lbs. 6 lbs. 15 lbs. 3 lbs.	5.6 to 7.5
3. Perennial ryegrass - tall fescue[2]	45 lbs. 45 lbs.	5.6 to 7.0
4. Tall fescue[2] - white clover[1]	75 lbs. 3 lbs.	5.5 to 7.5

Steep Banks and Cuts, Low-Maintenance Areas (not mowed)

Seed Mixtures	Rate per Acre Pure Live Seed	Optimum Soil pH
1. Smooth bromegrass - red clover[1]	50 lbs. 30 lbs.	5.5 to 7.5
2. Tall fescue[2] - white clover[1]	75 lbs. 3 lbs.	5.5 to 7.5
3. Tall fescue[2] - red clover	75 lbs. 30 lbs.	5.5 to 7.5
4. Orchardgrass - red clover[1] - white clover[1]	45 lbs. 30 lbs. 3 lbs.	5.6 to 7.0
5. Crownvetch[1] - tall fescue	18 lbs. 45 lbs.	5.6 to 7.0

Lawns and High-Maintenance Areas

Seed Mixtures	Rate per Acre Pure Live Seed	Optimum Soil pH
1. Bluegrass	210 lbs.	5.5 to 7.0
2. Perennial ryegrass (turf type) - bluegrass	90 lbs. 135 lbs.	5.6 to 7.0
3. Tall fescue (turf type)[2] - bluegrass	250 lbs. 45 lbs.	5.6 to 7.5

Channels and Areas of Concentrated Flow

Seed Mixtures	Rate per Acre Pure Live Seed	Optimum Soil pH
1. Perennial ryegrass - white clover[1]	225 lbs. 3 lbs.	5.6 to 7.0
2. Kentucky bluegrass - smooth bromegrass - switchgrass - timothy - perennial ryegrass - white clover[1]	30 lbs. 15 lbs. 5 lbs. 6 lbs. 15 lbs. 3 lbs.	5.5 to 7.5
3. Tall fescue[2] - white clover[1]	225 lbs. 3 lbs.	5.5 to 7.5
4. Tall fescue[2] - perennial ryegrass - Kentucky bluegrass	225 lbs. 30 lbs. 30 lbs.	5.5 to 7.5

[1] 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.

[2] Tall fescue provides little cover for, and may be toxic to some species of wildlife. The Indiana Department of Natural Resources recognizes the need for additional research on alternatives 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.

Notes:

1. If using mixtures other than those listed in this table, increase seeding rates by 50 percent over the conventional seeding rates.
2. A high potential for fertilizer, seed, and mulch to wash exists on steep banks, cuts, and in channels and areas of concentrated flow.

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Sod

The soil surface is stabilized by laying a continuous cover of grass ***sod*** *over soil exposed to erosive forces.*

Purpose

- To provide immediate vegetative cover on critically sloping areas, channels, and sediment control structures.
- To prevent erosion and damage from sedimentation.
- To reduce problems associated with mud or dust from unvegetated soil surfaces.

Specifications

Site Preparation

- Grade the site to achieve positive drainage.
- Prepare a smooth, firm soil surface and apply soil amendments.

Irrigation

Irrigate as needed to ensure rooting of sod.

Materials

- Soil Amendments – Select materials and rates as determined by a soil test (contact your county soil and water conservation district or cooperative extension office for assistance and soil information, including available soil testing services.) or 400 to 600 pounds of 12-12-12 analysis fertilizer, or equivalent.
- Sod – Select a high quality, healthy, vigorous 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.)

Installation

Sod should not be installed during hot weather, on dry soil, frozen soil, compacted clay, loose sand or gravelly substrate soils, aggregate, or pesticide-treated soil. The ideal time to lay sod is May 1 to June 1 or September 1 to September 30, although it can be installed as early as March 15 if available or June 1 to September 1 if irrigated.

Site Preparation

1. Apply topsoil (see **Topsoil Salvage and Utilization** on page 25) if existing soil conditions are unsuitable for establishing vegetation.
2. Grade the site to achieve positive drainage and create a smooth, firm soil surface.
3. Where applicable, use a chisel plow, disk, harrow, or rake to break up compacted soils and create a favorable rooting depth of six to eight inches.

Sod Bed Preparation

1. Test soil to determine pH and nutrient levels.
2. If soil pH is too acidic for the grass sod to be installed, apply lime according to soil test results or at the rate recommended by the sod supplier.
3. Apply fertilizer as recommended by the soil test. If testing was not done, apply 400 to 600 pounds per acre of 12-12-12 analysis fertilizer, or equivalent.
4. Work the soil amendments into the upper two to four inches of soil with a disk or rake operated across the slope.
5. Rake or harrow the area to achieve a smooth final grade and then roll or cultipack the soil surface to create a firm surface on which to lay the sod.

Laying the Sod

1. Install sod within thirty-six hours of its cutting.
2. Store the sod in a shaded location during installation.
3. Immediately before laying the sod, rake the soil surface to break any crust. (If the weather is hot, lightly irrigate the soil surface prior to laying the sod.)
4. Lay sod strips in a brick-like pattern (see Exhibit 1).
5. Butt all joints tightly against each other (do not stretch or overlap them), using a knife or mason's trowel to trim and fit sod into irregularly shaped areas.
6. Roll the sod lightly after installation to ensure firm contact between the sod and soil.

7. Irrigate newly sodded areas until the underlying soil is wet to a depth of four inches, and then keep moist until the grass takes root.

Slope Application

1. Install the sod strips with the longest dimension perpendicular to the slope.
2. Where slopes exceed a ratio of 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.)

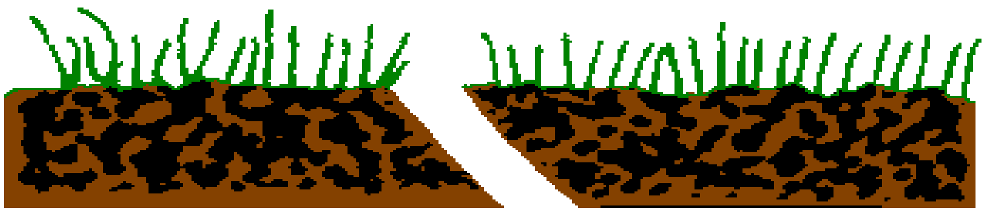
1. Excavate the channel, allowing for the full thickness of the sod.
2. Lay the sod strips with the longest dimension perpendicular to channel flow.
3. Staple or stake each strip of sod at the corners and in the middle.
4. Staple jute or biodegradable polypropylene netting over the sodded area to minimize the potential for washout during establishment.

Maintenance

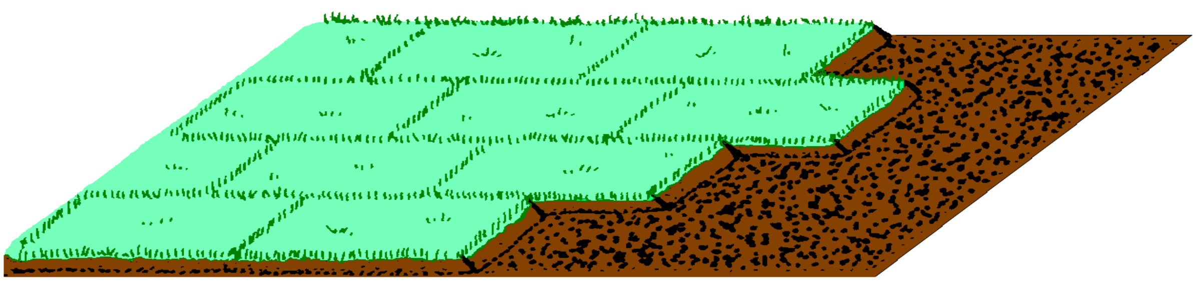
- Inspect within 24 hours of each rain event and at least once every seven calendar days until sod is well rooted.
- Keep sod moist until fully rooted.
- After sod is well-rooted (two to three weeks), maintain a plant height of two to three inches.
- Time mowing to avoid ruts in turf.
- Fertilize turf areas annually. Apply fertilizer in a split application. For cool-season grasses, apply one-half of the fertilizer in late spring and one-half in early fall. For warm-season grasses, apply one-third in early spring, one-third in late spring and one-third in mid-summer.

Exhibit 1

Cross-Section View



Perspective View



Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

Native & Warm Season Grasses

To be released at a later time

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Stabilization of Dune Areas

To be released at a later time

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Mulching

***Mulching** is the application of plant residues/materials to enhance and protect vegetative establishment and minimize erosion potential.*

Purpose

- To prevent erosion by protecting the soil from wind and water impact.
- To provide temporary surface stabilization.
- To prevent soil from crusting.
- To conserve soil moisture, moderate soil temperature, and promote seed germination and seedling growth.

Note: **This measure should not be used in storm water runoff channels or areas where concentrated flow is attempted.**

Specifications

Materials

Table 1. Mulch Specifications

Material[1]	Rate per Acre	Comments
Straw or hay	2 tons	Should be dry, free of undesirable seeds. Spread by hand or machine. Must be crimped or anchored (see *Table 2*).
Wood fiber or cellulose	1 ton	Apply with a hydraulic mulch machine and use with tacking agent.

[1] Mulching is not recommended in concentrated flows. Consider erosion control blankets or other stabilization methods.

Coverage

The mulch should have a uniform density of at least 75 percent over the soil surface.

Anchoring

Table 2. Mulch Anchoring Methods

Anchoring Method[1]	How to Apply
Mulch anchoring tool or farm disk (dull, serrated, and blades set straight)	Crimp or punch the straw or hay two to four inches into the soil. Operate machinery on the contour of the slope.
Cleating with dozer tracks	Operate dozer up and down slope to prevent formation of rills by dozer cleats.
Wood hydromulch fibers	Apply according to manufacturer's recommendations.
Synthetic tackifiers, binders, or soil stabilizers	Apply according to manufacturer's recommendations.
Netting (synthetic or biodegradable material)	Install netting immediately after applying mulch. Anchor netting with staples. Edges of netting strips should overlap with each up-slope strip overlapping four to six inches over the adjacent down-slope strip. Best suited to slope applications. In most instances, installation details are site specific, so manufacturer's recommendations should be followed.

[1] All forms of mulch must be anchored to prevent displacement by wind and/or water.

Application

1. Apply mulch at the recommended rate shown in Table 1.
2. Spread the mulch material uniformly by hand, hayfork, mulch blower, or hydraulic mulch machine. After spreading, no more than 25 percent of the ground should be visible.
3. Anchor straw or hay mulch immediately after application. The mulch can be anchored using one of the methods listed below:
   a. Crimp with a mulch anchoring tool, a weighted farm disk with dull serrated blades set straight, or track cleats of a bulldozer,
   b. Apply hydraulic mulch with short cellulose fibers,
   c. Apply a liquid tackifier, or
   d. Cover with netting secured by staples.

Maintenance

- Inspect within 24 hours of each rain event and at least once every seven calendar days.
- Check for erosion or movement of mulch; repair damaged areas, reseed, apply new mulch and anchor the mulch in place.
- Continue inspections until vegetation is firmly established.
- If erosion is severe or recurring, use erosion control blankets or other more substantial stabilization methods to protect the area.

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Compost Mulching

Source: U.S. Dept. of Agriculture, Natural Resources Conservation Service, Iowa, Lynn Betts

Compost mulching *is the application of composted materials to enhance vegetative establishment and minimize erosion potential.*

Purpose

- To protect exposed soil from the erosive forces of wind and water.
- To provide temporary surface stabilization.
- To prevent soil from crusting.
- To conserve soil moisture and promote seed germination and seedling growth.

Note: **This measure should not be used in storm water runoff channels or anywhere that concentrated flow is anticipated.**

Specifications

Compost Specifications

- Feedstocks may include but are not limited to well-composted vegetable matter, leaves, yard trimmings, food scraps, composted manures, paper fiber, wood bark, Class A biosolids (as defined in Title 40 of the Code of Federal Regulations at 40 CFR Part 503), or any combination thereof.
- Compost shall be produced using an aerobic composting process meeting 40 CFR Part 503 regulations, including time and temperature data indicating effective weed seed, pathogen, and insect larvae kill.
- Compost shall be well decomposed, stable, and weed free.

- Refuse free (less than one percent by weight).
- Free of any contaminants and materials toxic to plant growth.
- Inert materials not to exceed one percent by dry weight pH of 5.5 to 8.0.
- Carbon-nitrogen ratio not to exceed 100.
- Moisture content not to exceed 45 percent by dry weight.
- Variable particle size with maximum dimensions of three inches in length, one-half inch in width and one-half inch in depth.

Table 1. Compost Particle Size

Percent Passing Sieve Size			
2-Inch Sieve	1-Inch Sieve	¾-Inch Sieve	> ¼-Inch Sieve
100%	99%	90%	25%

Bonding Agents (optional)

Tackifiers, flocculants, or microbial additives may be used to remove sediment and/or additional pollutants from storm water runoff. (All additives combined with compost materials should be tested for physical results at a certified erosion and sediment control laboratory and biologically tested for elevated beneficial microorganisms at a United States Compost Council, Seal of Testing Assurance, approved testing laboratory.)

Soil Material (optional)

Five percent to ten percent sandy loam (as classified by the U.S. Department of Agriculture soil classification system).

Cover Density

Ninety percent or greater over the soil surface.

Anchoring Method

- Moisten compost/mulch blanket for a minimum of 60 days.
- Erosion control netting (optional).

Cover Thickness

Table 2. Compost Blanket Thickness

Slope		Thickness of Compost Blanket	Thickness of Compost Blanket with Erosion Control Netting
< 25%	< 4:1	1 to 2 inches	Not Applicable
25% to 50%	4:1 to 2:1	1 to 2 inches	2 inches
> 50%	> 2:1	2 to 3 inches	3 inches

Application

1. Remove existing vegetation, large soil clods, rocks, stumps, large roots, and debris in areas where compost mulch is to be applied and dispose of in designated areas.
2. Scarify sloping areas.
3. Aerate areas to be covered with compost/mulch blanket. (Proper aeration will require a minimum of two passes oriented in opposite directions.)
4. Broadcast a minimum of one pound of nitrogen (N), one-half pound of phosphorous (P_2O_5), and one-half pound of potash (K_2O) per 1,000 square feet or 300 to 400 pounds per acre of 12-12-12 analysis fertilizer, or equivalent, per acre.
5. Apply compost mulch blanket with a pneumatic blower or per manufacturer's directions.
   a. Apply within three days of completing aeration operations.
   b. Overlap top of slope shoulder by five to ten feet.
   c. Seed may be applied at time of installation. (Seed must be evenly blended into the compost if applied with a pneumatic blower or applied with a calibrated seeder attachment prior to installation of the compost blanket.)
6. Water compost mulch blanket for a period of 60 days following application. (On steeper slopes, it may be necessary to install erosion control netting over the compost blanket.)
   a. Mist blanket for first seven days and then every three days throughout the remainder of the 60-day period.
   b. Maintain a constant moisture content of 40 percent to 60 percent.

Maintenance

- Inspect within 24 hours of a rain event and at least once every seven calendar days.
- Repair eroded areas.
- Reseed, if applicable.
- Monitor vegetation and apply appropriate soil amendments (if needed) per a soil test.

Erosion Control Blanket

An ***erosion control blanket*** *is a biodegradable, organic or synthetic mulch incorporated with a biodegradable, photodegradable, or permanent polypropylene, natural fiber, or similar netting material. It is an alternative to mulch and normally used on slopes and in concentrated flow channels.*

Purpose

- 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 and concentrated flow conveying systems.
- To reduce soil crusting.
- To conserve soil moisture and increase seed germination and seedling growth.

Specifications

Effective Life

The functional life of an erosion control blanket is dependent on the materials used.

Anchoring

Staples, pins or stakes used to prevent movement or displacement of blanket. (Follow manufacturer's recommendations for specific applications.)

Materials

- Organic (straw, excelsior, woven paper, coconut fiber, etc.) or synthetic mulch incorporated with a polypropylene, natural fiber or similar netting material. (The netting may be biodegradable, photodegradable or permanent.)

Note: **Some erosion control blanket nettings may pose a threat to certain species of wildlife if they become entangled in the netting matrix.**

- Six to 12-inch staples, pins, or stakes.

Installation

1. Select the type and weight of erosion control blanket to fit the site conditions (e.g., slope, channel, flow velocity) per the manufacturer's specifications.
2. Prepare the seedbed, add soil amendments, and permanently seed (see **Permanent Seeding** on page 35) the area immediately following seedbed preparation.
3. Lay erosion control blankets on the seeded area so that they are in continuous contact with the soil with each up-slope or up-stream blanket overlapping the down-slope or down-stream blanket by at least eight inches, or follow manufacturer's recommendations.
4. Tuck the uppermost edge of the upper blankets into a check slot (slit trench), backfill with soil and tamp down. In certain applications, the manufacturer may require additional check slots at specific locations down slope from the uppermost edge of the upper blankets.
5. Anchor the blankets in place by driving staples, pins, or stakes through the blanket and into the underlying soil. Follow an anchoring pattern appropriate for the site conditions and as recommended by the manufacturer.

Maintenance

- Inspect within 24 hours of each rain event and at least once every seven calendar days.
- Check for erosion or displacement of the blanket.
- If any area shows erosion, pull back that portion of the blanket covering the eroded area, add soil and tamp, reseed the area, replace and staple the blanket.

Turf Reinforcement Mat

*A **turf reinforcement mat** is a three-dimensional matrix of polypropylene, nylon, or other material typically used in channel applications or on slopes to reinforce plant rooting systems and the underlying soil material.*

Purpose

- To provide reinforcement to vegetation in areas of concentrated flow or steep slopes where other types of stabilization, such as riprap, are not feasible or desired.
- To provide surface stabilization.
- To provide reinforcement for plant roots as vegetation is being established.

Specifications

Effective Life

The functional life of turf reinforcement mat is dependent on the materials used.

Anchoring

Staples, pins, or stakes used to prevent movement or displacement of mat. (Follow manufacturer's recommendations for specific applications.)

Materials

- Turf reinforcement mat (typically consists of a three-dimensional matrix of polypropylene, nylon, or other material).
- Six to 12-inch staples, pins, or stakes.

Installation

1. Select a turf reinforcement mat appropriate for the site conditions (e.g., slope, channel, flow velocity) per the manufacturer's specifications.
2. Grade and prepare the soil foundation for mat installation.
3. Install the mat according to the manufacturer's instructions, including burying the edges in check slots or slit trenches.
4. Anchor the mat in place by driving staples, pins, or stakes through the mat and into the underlying soil. Follow an anchoring pattern appropriate for the site conditions and as recommended by the manufacturer.
5. Backfill the mat with topsoil, filling to the top of the mat.
6. Seed the area after the mat has been installed and backfilled with soil.
7. Install erosion control blankets over the seeded turf reinforcement mat to stabilize the surface.

Note: **Some products may not require backfill of topsoil or the application of erosion control blankets. Consult manufacturer's literature for proper installation guidance.**

Maintenance

- Inspect within 24 hours of each rain event and at least once every seven calendar days.
- Check for erosion or displacement/exposure of the mat.
- If a specific area shows erosion, add soil and restabilize.

Soil Stabilizers

To be released at a later time

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Riprap Slope Protection

Riprap slope protection *is an erosion control measure consisting of geotextile fabric and stone riprap that is placed on an unvegetated slope to protect the soil from erosive forces.*

Purpose

To protect slopes or similar areas subject to erosion by water.

Specifications

Slope

A ratio of 2:1 or flatter (designed by a qualified individual/professional engineer; slopes exceeding 2:1 may require additional design considerations).

Minimum Thickness

Two times the designed d_{50} (see Appendix A – Glossary) stone diameter plus the depth of the bedding material.

Materials

- Riprap
  - Hard, angular, and weather resistant.
  - Specific gravity of at least 2.5.
  - Size and gradation that will withstand velocities of storm water discharge flow design.
  - Well-graded mixture of stone with 50 percent of the stone pieces, by weight, larger than the designed d_{50} size.
  - Largest pieces should not exceed two times the designed d_{50} and no more than 15 percent of the pieces (by weight) should be less than three inches.

- Bedding Material – Geotextile fabric, sand, or crushed aggregate [Indiana Department of Transportation CA No. 9, 11, or 12 (see Appendix D)].

Installation

Subgrade Preparation

1. Remove brush, trees, stumps, and other debris and dispose of in designated areas.
2. Excavate foundation subgrade below design elevation to allow for thickness of the bedding material and riprap.
3. Compact any fill material to the density of the surrounding undisturbed soil.
4. Cut a keyway in stable material at the slope base to reinforce the toe; keyway depth should be one and one-half times the design thickness of the stone and should extend a horizontal distance equal to the design thickness (see Riprap Slope Protection Worksheet).
5. Smooth the graded foundation.

Placement of Bedding Material

1. If using geotextile fabric, place on the smoothed foundation, overlap the edges at least 12 inches and secure with anchor pins spaced every three feet along the overlap. (For large riprap, consider a four inch layer of sand to protect the fabric.)
2. If using sand or aggregate bedding material, spread the well-graded bedding material in a uniform layer to the required thickness (six inches minimum). If two or more layers are specified, place the layer of the smaller gradation first and avoid mixing the layers.

   Note: **Omission of the bedding material or damage to it may result in erosion and/or piping beneath the riprap or movement of the underlying soil through the voids in the riprap.**

Riprap Placement

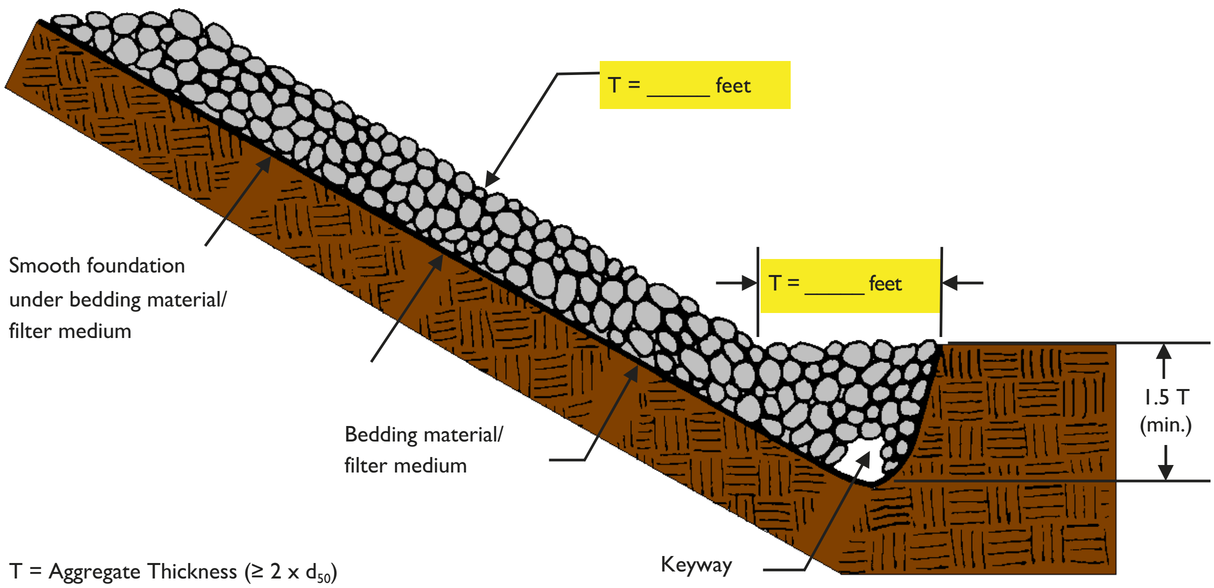
1. Immediately after installing the bedding material, add riprap to the lines and elevations shown in the construction plans. Place the riprap in one operation, taking care not to damage the bedding material. (Do not dump through chutes or use any method that causes segregation of stone sizes or that will dislodge or damage the underlying bedding material.)
2. If geotextile fabric tears when placing riprap, repair immediately by laying and stapling a piece of fabric over the damaged area, overlapping the undamaged areas by at least 12 inches.

3. Place smaller stone in voids to form a dense, uniform, well-graded riprap mass. (Selective loading at the quarry and some hand placement may be needed to ensure an even distribution of stone material.)
4. Blend the riprap surface smoothly with the surrounding area to eliminate protrusions or overfalls.

Maintenance

- Inspect within 24 hours of each rain event and at least once every seven calendar days.
- Check for displacement of riprap material, slumping, and erosion along the edges, especially on the down-slope side. (Properly designed and installed riprap usually requires very little maintenance.)

Riprap Slope Protection Worksheet



Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

RUNOFF CONTROL

Runoff controls are important in effectively controlling and managing storm water runoff. Measures included in this section of the manual are designed to reduce the velocity of storm water runoff by reducing slope lengths (e.g., diversions and water bars); carry concentrated runoff down slopes and channels without causing erosion (e.g., temporary slope drains, grade breaks, and check dams); and collect storm water runoff (e.g., temporary and permanent diversions) and transport it to sediment control devices such as sediment traps and basins. Depending on the situation, several of the measures included in this section may also provide for some additional sediment trapping.

Many of the measures in this section can also be used to divert surface water runoff away from unvegetated work areas. Diversion of runoff away from work areas generally results in less water flowing across the work site which means lower erosion potential. Lower quantities of runoff will also allow for the installation of smaller sediment treatment devices.

Designs for runoff control measures can be complex and generally require detailed site investigations and the application of sound engineering principles. A professional knowledgeable of the principles of storm water management and experienced in structural design should be consulted when using runoff control measures.

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Temporary Diversion

*A **temporary diversion** is a storm water control measure consisting of a temporary ridge, excavated channel, or combination of a channel and supporting ridge constructed on a predetermined grade across a slope to collect storm water runoff and divert it to a treatment device or stable outlet.*

Purpose

- To temporarily direct storm water runoff in a controlled manner to a desired location.
- To protect work areas from storm water runoff.
- To manipulate watershed areas for sizing of sediment controls/measures.

Specifications

Contributing Drainage Area

Three acres maximum. (Larger drainage areas may be accommodated, but may require additional design considerations.)

Capacity

Peak runoff from a two-year frequency, 24-hour duration storm event.

Ridge

- Side slope – A ratio of 2:1 or flatter (3:1 or flatter if mowed).
- Top width – two feet minimum.
- Freeboard – six inches minimum.
- Settlement – 10 percent of fill height.
- Stabilized if in place more than 15 working days.

Channel

- Shape – parabolic, trapezoidal, or V-shaped.
- Side slopes – ratio of 2:1 or flatter (3:1 or flatter if mowed).
- Depth – 18 inches minimum.
- Grade – positive towards outlet, but not exceeding one percent.
- Stabilized for design flow.

Outlet

Stable, with sediment-laden water diverted to a sediment trap or basin.

Installation

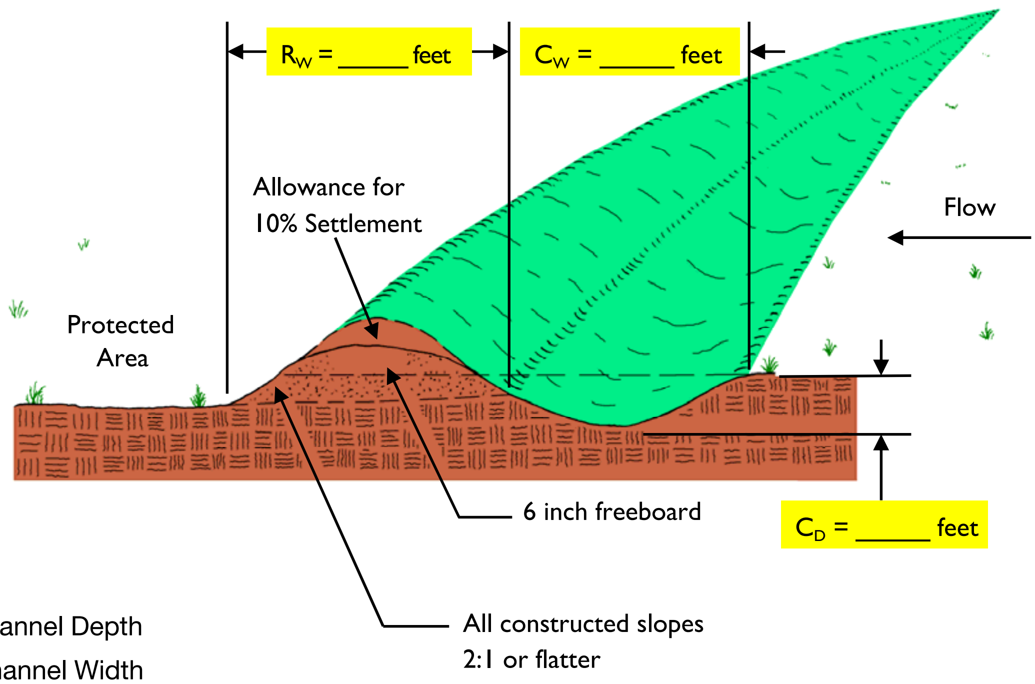
1. Lay out the diversion by setting grade and alignment to fit site needs and topography, maintaining a stable, positive channel grade towards the outlet.
2. Remove and properly dispose of brush, trees, and other debris from the foundation area.
3. Construct the diversion to dimensions and grades shown in the construction plans.
4. Construct the diversion ridge in six to eight-inch lifts. Compact each lift by driving wheels of construction equipment along the ridge. Overfill and compact the ridge to design height plus 10 percent to allow for settlement. (The compacted ridge must be at or above design grade at all points, while the channel must be at design grade. Leave sufficient area along the diversion to permit cleanout and regrading.)
5. Stabilize outlets prior to or during construction of the diversion, diverting sediment-laden storm water flow to a temporary sediment trap (see **Temporary Sediment Trap** on page 183) or a temporary dry sediment basin (see **Temporary Dry Sediment Basin** on page 191).

   Note: **Temporary diversions are also used in conjunction with temporary slope drains (see Temporary Slope Drain on page 103) or other appropriate sediment control measures.**

Maintenance

- Inspect within 24 hours of each rain event and at least once every seven calendar days.
- Remove sediment from channel to maintain positive grade.
- Check outlets and make necessary repairs immediately.
- Adjust ridge height to prevent overtopping.

Temporary Diversion Worksheet



C_D = Channel Depth

C_W = Channel Width

R_W = Ridge Width

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Permanent Diversion

*A **permanent diversion** is a storm water control measure consisting of a permanent channel and supporting ridge constructed on a predetermined grade across a slope to collect storm water runoff and divert it to a treatment device or stable outlet.*

Purpose

To divert storm water runoff to a location where it can be stored, used, or released without causing erosion or flood damage.

Specifications

Contributing Drainage Area

50 acres maximum. (Designed by a qualified individual/professional engineer. Larger drainage areas may be accommodated but may require additional design considerations.)

Capacity

Peak runoff from 25-year frequency, 24-hour duration storm event (or higher capacity where safety is a concern or flood damage cannot be tolerated).

Ridge

- Side slope – ratio of 2:1 or flatter (3:1 or flatter if mowed).
- Top width – four feet minimum.
- Freeboard – six inches minimum.
- Settlement – 10 percent of fill height.
- Stabilized with vegetation.

Channel

- Shape – parabolic.
- Side slopes – ratio of 2:1 or flatter (3:1 or flatter if mowed).
- Depth – 18 inches minimum.
- Grade – positive towards outlet, but not exceeding two percent.
- Stabilized with vegetation or appropriate armor based on design flow.

Outlet

Stable, with sediment-laden water diverted to a sediment trap or basin.

Subsurface Drain (optional)

- Installed off to the side of the channel bottom (to eliminate seepage from channel side slopes).
- Perforated drain tile.
- Depth – two feet minimum.

Installation

1. Lay out the diversion by setting grade and alignment to fit site needs and topography, maintaining a stable, positive channel grade towards the outlet.
2. Remove and properly dispose of brush, trees, and other debris from the foundation area.
3. Disk ridge base before placing fill to allow bonding of soil materials.
4. Excavate the channel and fill/shape the diversion ridge to alignment, grade and cross-section shown in the construction plans.
   Note: **Install subsurface tile drain where a seasonal high water table exists.**
5. Construct the ridge in six to eight-inch lifts, compacting each lift as it is placed. Build the diversion ridge higher than design elevation, allowing for 10 percent settlement. (Compaction of the ridge may be achieved by driving wheeled equipment along the ridge as soil lifts are added. The compacted ridge must be at or above design grade at all points, while the channel must be at design grade. Shape the ridge and channel to blend with the surrounding landscape and leave sufficient area along the diversion to permit cleanout and regrading.)
6. Stabilize outlets prior to or during construction of the diversion diverting sediment-laden storm water flow to a temporary sediment trap (see **Tempo-**

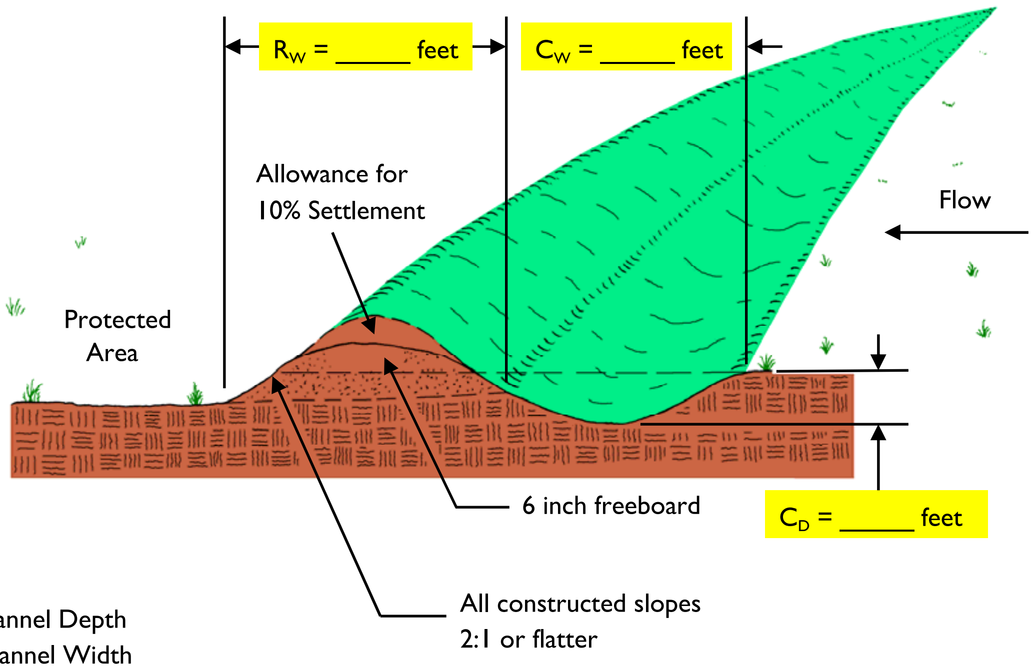
rary Sediment Trap on page 183) or a temporary dry sediment basin (see **Temporary Dry Sediment Basin** on page 191) or other appropriate sediment control measures.

7. Stabilize diversions immediately after construction using vegetation and/or other suitable linings (e.g., riprap). If vegetation is used (see **Permanent Seeding** on page 35), protect newly seeded areas with properly anchored mulch (see **Mulching** on page 55), erosion control blankets (see **Erosion Control Blanket** on page 63), or by installing sod (see **Sod** on page 47).

Maintenance

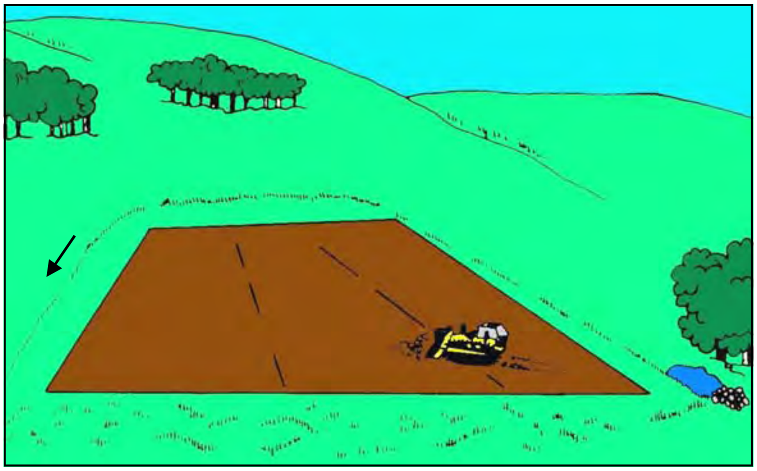
- Inspect within 24 hours of each rain event and at least once every seven calendar days.
- Remove sediment from channel to maintain positive grade.
- Check outlets and make necessary repairs immediately.
- Adjust ridge height to prevent overtopping.

Permanent Diversion Worksheet



C_D = Channel Depth
C_W = Channel Width
R_W = Ridge Width

Perimeter Diversion Dike



Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

*A **perimeter diversion dike** is a storm water control measure, consisting of a dike or dike and channel, constructed along the up-slope perimeter of an unvegetated construction site to control storm water runoff from undisturbed areas and divert it around the construction zone.*

Purpose

To prevent storm water runoff from entering a construction site thereby reducing erosion potential and the volume of storm water runoff that will require treatment for sediment capture.

Specifications

Contributing Drainage Area

- Five acres maximum. (Designed by a qualified individual/professional engineer. Larger drainage areas may be accommodated but may require additional design considerations.)

Capacity

- Peak runoff from a two-year frequency, 24-hour duration storm event.

Ridge

- Side slope – ratio of 2:1 or flatter (3:1 or flatter if mowed).
- Top width – two feet minimum.
- Height – one and one-half feet minimum from channel bottom.
- Freeboard – six inches minimum.
- Settlement – 10 percent of fill height.
- Stabilized immediately after construction.

Channel

- Shape – parabolic, trapezoidal, or V-shaped.
- Side slopes – ratio of 2:1 or flatter.
- Depth – 18 inches minimum.
- Grade – positive towards outlet, but not exceeding two percent.
- Stabilized for design flow.

Outlet

- Stable, with sediment-laden water diverted to a sediment trap or basin and storm water runoff from undisturbed areas diverted to a stable natural outlet or outlet stabilization structure.

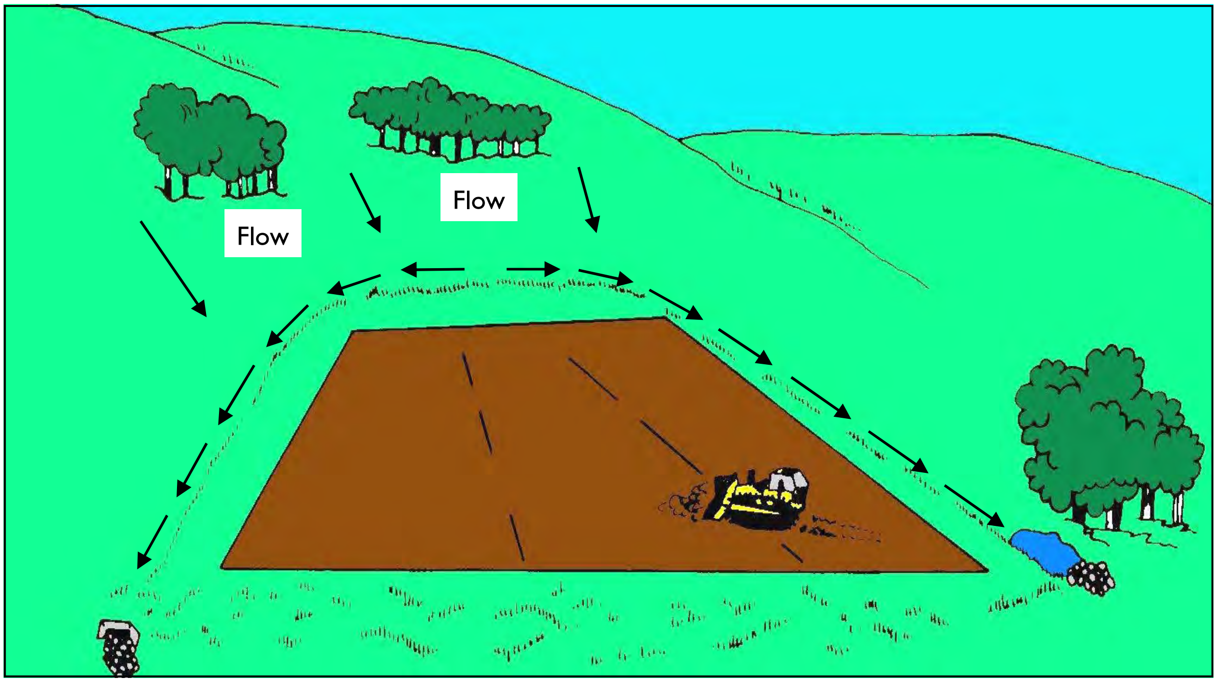
Installation

1. Lay out the diversion by setting grade and alignment to fit site needs and topography, maintaining a stable, positive channel grade towards the outlet. Caution: **Water diverted from the construction site must not damage adjacent property.**
2. Remove and properly dispose of brush, trees, and other debris from the foundation area.
3. Fill and compact all ditches and gullies to be crossed.
4. Remove topsoil and scarify the subsoil. Prepare ridge foundation so its elevation is at or above surrounding ground elevation.
5. Construct the diversion dike and channel to dimensions and grades shown in the construction plans.
6. Construct the diversion dike ridge in six to eight-inch lifts. Compact each lift by driving wheels of construction equipment along the ridge. Overfill and compact the ridge to design height plus 10 percent to allow for settlement. (The compacted ridge must be at or above design grade at all points, while the channel must be at design grade. Shape the ridge and channel to blend with the surrounding landscape and leave sufficient area along the diversion to permit cleanout and regrading.)
7. Install outlet protection and sediment traps and basins where appropriate as part of the diversion dike. All outlets must be stable.
8. Establish vegetation (see **Temporary Seeding** on page 31; **Permanent Seeding** on page 35; **Sod** on page 47; and **Mulching** on page 55) on dike immediately following construction and stabilize the diversion channel with an erosion resistant lining (e.g., riprap).

Maintenance

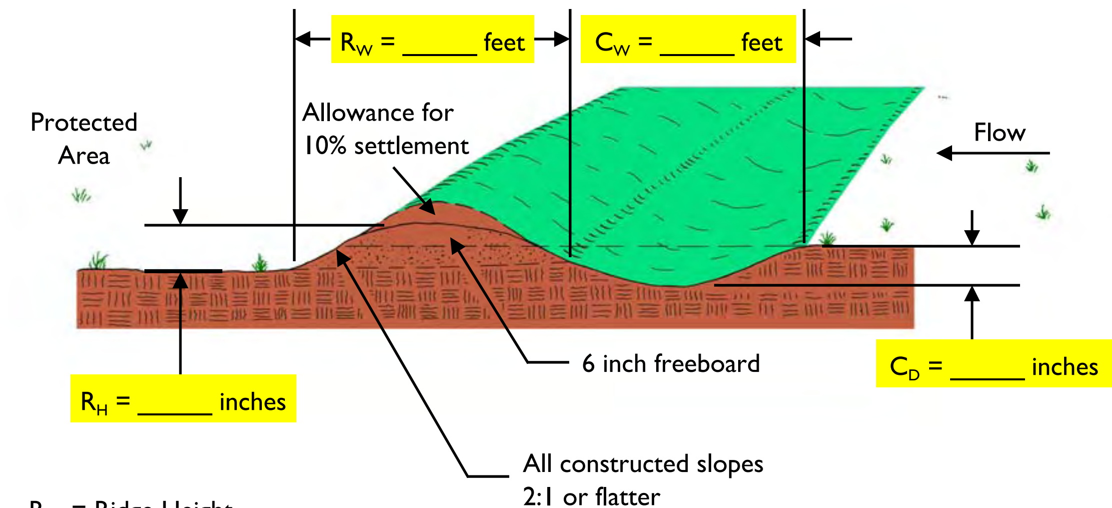
- Inspect within 24 hours of each rain event and at least once every seven calendar days.
- Remove sediment and debris from channel to maintain positive grade.
- Repair dike to its original height.
- Check outlets and make necessary repairs to prevent gully formation.
- Once the work area has been stabilized, remove diversion ridge, fill and compact channel to blend with surrounding area, and stabilize with vegetation.

Exhibit 1



Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

Perimeter Diversion Dike Worksheet



R_H = Ridge Height
R_W = Ridge Base Width
C_D = Channel Depth
C_W = Channel Top Width

Note: Drainage channel is optional.

Water Bar

*A **water bar** is a series of small ridges or ridges and channels used to intercept and divert storm water runoff from long, narrow corridors and discharge it into a stabilized area or sediment treatment device.*

Purpose

To temporarily reduce erosion on narrow, long, sloping corridors by diverting storm water runoff at selected intervals.

Specifications

Corridor Width

100 feet maximum.

Water Bars

- Spacing – as shown in Table 1.
- Ridge
  - Height – nine inches minimum from down-slope ground level to top of settled ridge.
  - Base width – six feet minimum.
- Side slope – ratio of 2:1 or flatter.
- Alignment – stable, positive grade towards outlet, but not exceeding two percent.
- Settlement – 10 percent of fill height.

Outlet

- Water bar must cross full corridor width and extend to a stable outlet.
- Diversion grade near outlet should be reduced to one percent or less to slow storm water discharge velocities at outlet.

Table 1. Water Bar Spacing

Slope		Spacing
< 5%	< 20:1	125 feet
5% to 10%	20:1 to 10:1	100 feet
10% to 20%	10:1 to 5:1	75 feet
20% to 33%	5:1 to 3:1	50 feet
>33%	> 3:1	25 feet

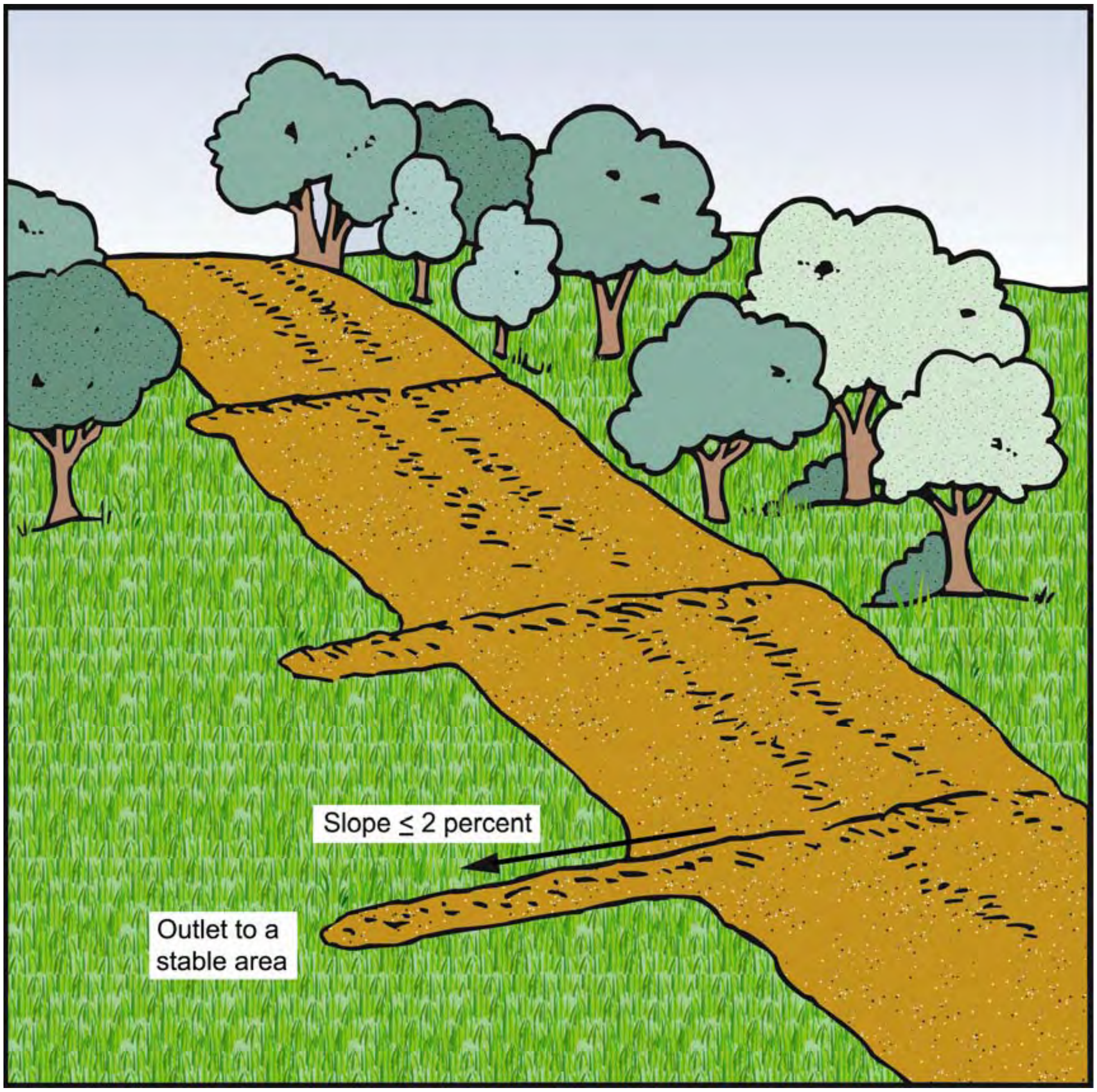
Installation

1. Remove and properly dispose of brush, trees, and other debris from the corridor.
2. Lay out (set) the water bars to the lines and dimensions shown in the construction plans, locating the first water bar at the required distance from the slope crest depending on steepness of the corridor slope.
3. Mark the locations and widths of the remaining water bars. If necessary, adjust length and/or spacing between water bars to prevent runoff from up-slope water bars converging with outlets of down-slope water bars.
4. Lay out the direction of the water bars to utilize the most stable outlet locations. Set water bar crossing angles to maintain a positive grade of less than two percent towards the outlet.
5. Construct sediment traps or outlet stabilization structures as needed.
6. Clear and grade the foundation for the water bars.
7. Disk the entire length of the water bar foundation.
8. Construct the water bar ridge in six to eight-inch lifts. Compact each lift by driving wheels of construction equipment along the ridge. Overfill and compact the ridge to design height plus 10 percent to allow for settlement.
9. Establish vegetation (see **Temporary Seeding** on page 31; **Permanent Seeding** on page 35; **Sod** on page 47; and **Mulching** on page 55) on water bar ridges immediately following construction or stabilize with a nonerosive cover.

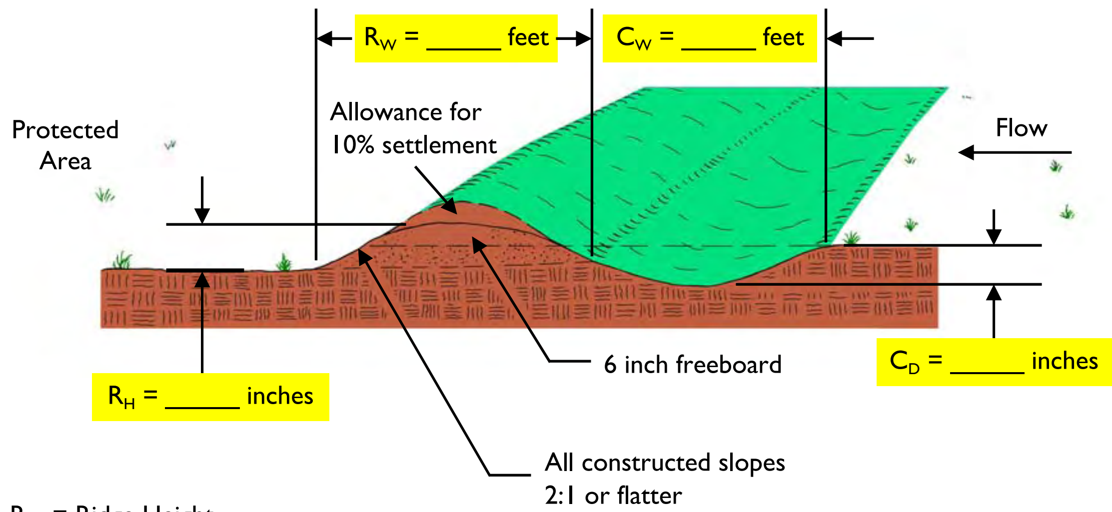
Maintenance

- Inspect within 24 hours of each rain event and at least once every seven calendar days. Frequency of equipment action may require daily inspection.
- Inspect for erosion and sediment deposition; remove debris and sediment from channels and sediment traps or basins.
- Repair ridges to grade and design height.
- Inspect for vehicular wear; add aggregate at vehicle crossing areas when necessary.
- Inspect outlets and stabilize as needed.
- Repair and stabilize water bars immediately after installation of utilities in right-of-way.
- To remove temporary water bars, grade ridge and channel to blend with natural ground, compact channel fill and stabilize disturbed areas. Do not remove water bars until all disturbed areas draining into them are stabilized.

Exhibit 1



Water Bar Worksheet



R_H = Ridge Height
R_W = Ridge Base Width
C_D = Channel Depth
C_W = Channel Top Width

Note: Drainage channel is optional.

Grade Breaks

To be released at a later date

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Rock Check Dam

*A **rock check dam** is a series of runoff control structures, consisting of geotextile fabric and aggregate, placed across drainage channels to slow storm water runoff. This measure may also provide limited effectiveness as a sediment control measure.*

Purpose

- To reduce erosion in a drainage channel by slowing velocity of flow. (Check dams are commonly used (a) in channels that are eroding, 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.)
- To reduce flow velocities in a drainage channel.

  Note: **Do not use check dams in perennial streams.**

Specifications

Contributing Drainage Area

Two acres maximum.

Riprap Check Dam

- Dam height.
  - Two feet maximum.
  - center of the dam at least nine inches lower than the points of contact between the uppermost points of the riprap dam and channel banks.
- Side slope – ratio of 2:1 or flatter.
- Spacing – toe of the upstream dam at same elevation as overflow weir of the downstream dam.

Overflow Areas

Stabilized to reduce scour/erosion along sides and below the dam.

Filter Medium

- Placed on up-slope side of dam.
- Height – to base of overflow weir notch.

Materials

- Geotextile fabric (8 ounce or heavier; nonwoven).
- Indiana Department of Transportation Revetment riprap (see Appendix D) for dam.
- INDOT CA No. 5 aggregate (see Appendix D) for use as filter medium (Aggregate must be well-graded).

Note: **INDOT CA No. 8 aggregate is acceptable if No. 5 aggregate is not available. The use of No. 8 aggregate may result in more frequent overtopping of the structure and will increase the frequency of structure maintenance.**

Installation

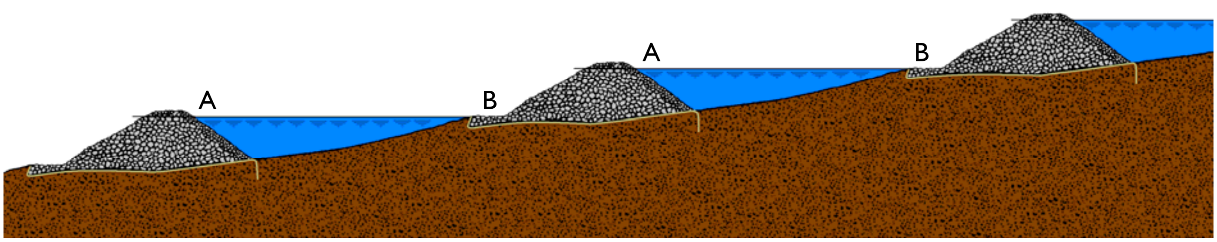
1. Lay out the location of the check dam.
2. Excavate a cutoff trench into the channel bottom and ditch banks, extending it a minimum of 18 inches beyond the top of the ditch bank.
3. Install and anchor filter fabric in the channel and cutoff trench.
4. Place riprap in the cutoff trench and channel to the lines and dimensions shown in the construction plans. The center of each dam must be at least nine inches lower than the uppermost points of contact between the riprap dam and channel banks (see Rock Check Dam Worksheet on page 101).
5. Extend the riprap at least 18 inches beyond the top of the channel banks to keep overflow water from eroding areas adjacent to the channel banks before it re-enters the channel.
6. Place filter medium (INDOT CA No. 5 aggregate) on the up-slope side of the dam. Place filter medium over the entire face of the dam up to the base of the overflow weir notch.
7. Stabilize the channel above the uppermost dam.
8. Install an erosion-resistant lining in the channel below the lowermost dam. The lining should extend a minimum distance of six feet below the dam.

9. Additional sediment storage can be provided by excavating a small sediment trap on the upstream side of the check dam.

Maintenance

- Inspect within 24 hours of each rain event and at least once every seven calendar days.
- If significant erosion occurs between dams, install an erosion-resistant liner in that portion of the channel.
- Remove accumulated sediment when it reaches one-half the height of the dam to maintain channel capacity, allow drainage through the dam, and prevent large flow from displacing sediment.
- Add riprap and aggregate as needed to maintain design height and cross section of the dams.
- When dams are no longer needed, remove the riprap and aggregate and stabilize the channel, using an erosion-resistant lining if necessary. (Riprap and aggregate from the dam may be removed or utilized to stabilize the channel.)

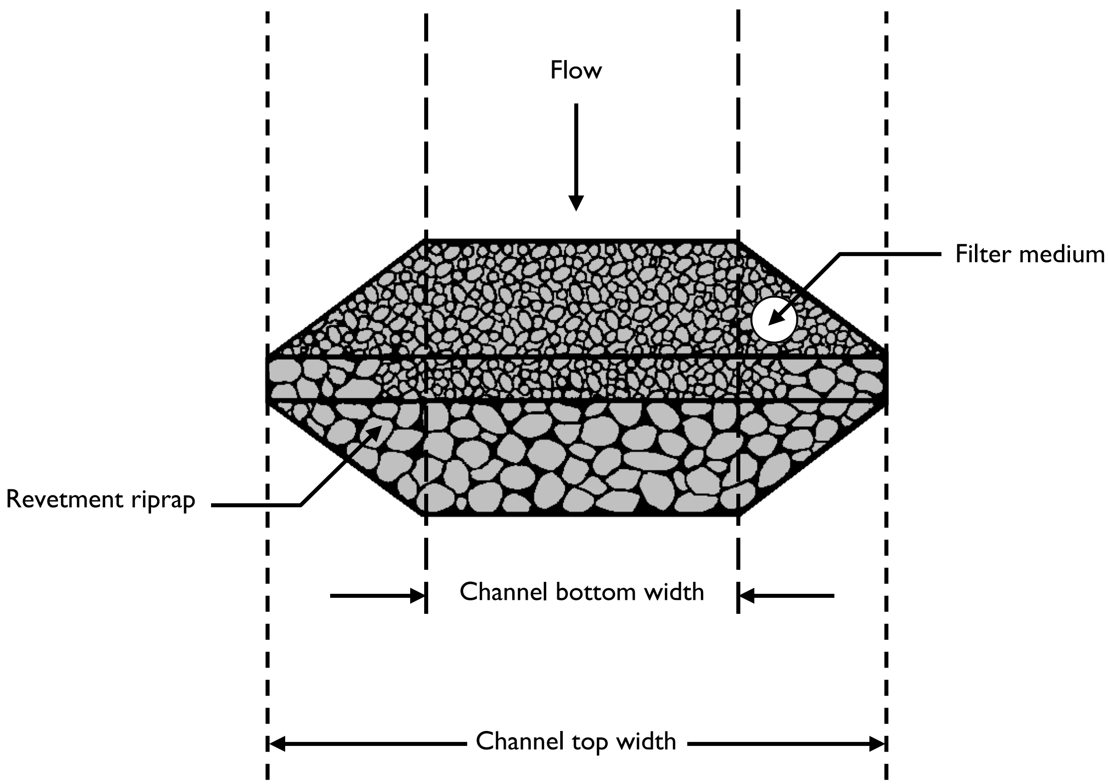
Exhibit 1



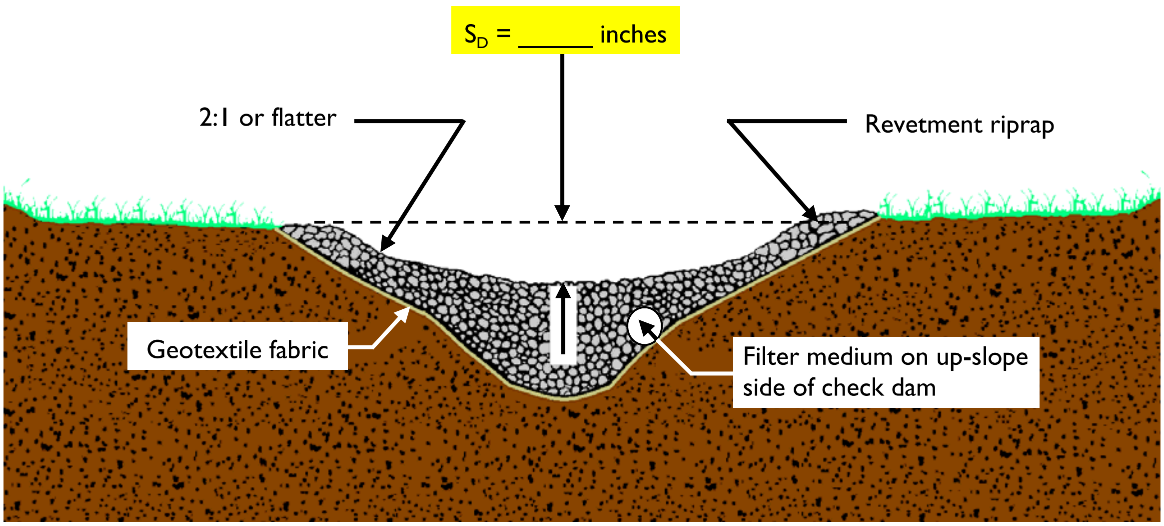
A = Crest of Dam

B = Toe of Dam

Exhibit 2

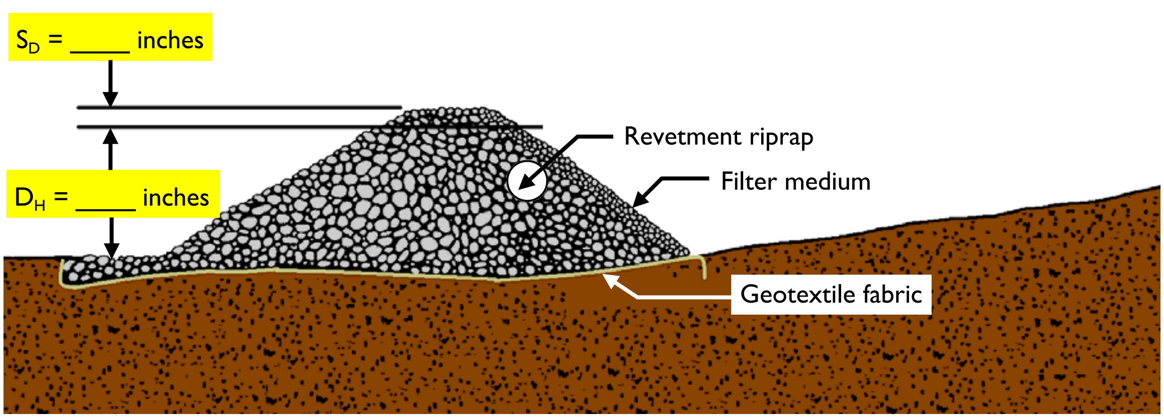

Flow
Filter medium
Revetment riprap
Channel bottom width
Channel top width

Rock Check Dam Worksheet



S_D = Spillway Depth

NOTE: For minimum dimensions see the "Specifications" section of this measure.



D_H = Dam Height
S_D = Spillway Depth

NOTE: For minimum dimensions see the "Specifications" section of this measure.

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

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Temporary Slope Drain

*A **temporary slope drain** is a temporary storm water control measure consisting of flexible or rigid tubing or conduit placed and anchored on an unvegetated slope to convey storm water runoff from the top of the slope to the bottom of the slope without causing erosion of the slope surface.*

Purpose

To temporarily convey storm water runoff down the face of a slope without causing erosion.

Specifications

Capacity

Peak runoff from two-year frequency, 24-hour duration storm event.

Pipe Size

Based on drainage area as shown in Table 1.

Table 1. Pipe Size Selection

Maximum Drainage Area per Pipe	Minimum Pipe Diameter
0.50 acre	8 inch
0.75 acre	10 inch
1.00 acre	12 inch
> 1.00 acre	Individually designed

Inlet Section

- Standard "T" or flared-end section (see Figure 1).
- Compacted fill over pipe
  - Depth – one and one-half feet minimum.
  - Width – four feet minimum.
  - Height – six inches higher than the diversion ridge.

Figure 1: Temporary Slope Drain with Flared-End Section

Outlet

- Pipe extended beyond the toe of the slope.
- Pipe terminated on a stable, four-foot long (minimum), level section.

Materials

- Pipe – Strong, flexible pipe, such as heavy-duty, non-perforated, corrugated plastic.
- “T” or flared-end section.
- Wooden stakes or rebar.

Installation

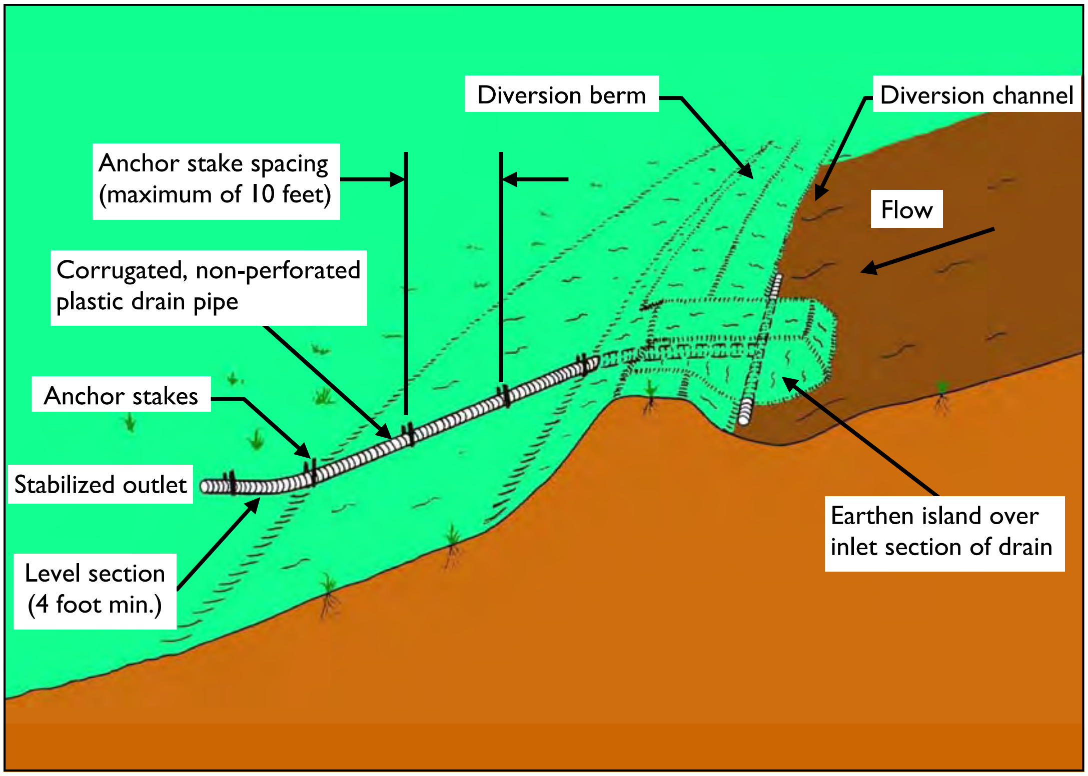
1. Lay the pipe down the slope face and anchor it in place with stakes no more than 10 feet apart (see Temporary Slope Drain Worksheet on page 107). Note: **Place temporary slope drains on undisturbed soil or well-compacted fill.**
2. Extend the pipe beyond the toe of the slope to a stable grade and terminate the pipe on a four-foot level section to protect the outlet from erosion.
3. Install a sediment trap or basin to capture sediment-laden water discharged from the pipe.
4. Set the slope drain inlet section at the bottom of the diversion channel.
5. Connect the pipe to the inlet section.

6. Construct a ridge over the inlet section of pipe by placing fill over the pipe in six-inch lifts.
7. Compact each lift by hand tamping under and around the inlet and along the pipe. Caution: **Compacting with heavy equipment may displace or collapse the pipe.**
8. Repeat steps 6 and 7 until the minimum depth, width, and side slope dimensions shown in the construction plans are reached. Making the top of the fill six inches higher than the adjoining diversion ridge creates an island over the pipe to prevent overtopping (see Temporary Slope Drain Worksheet).
9. Make all pipe connections watertight and secure so that joints will not separate in use.
10. Construct a temporary diversion channel (see **Temporary Diversion** on page 75) towards the temporary slope drain. The diversion must have a stable, positive grade not exceeding two percent.
11. Following installation, stabilize all areas down slope of the diversion and where practical, all disturbed areas.

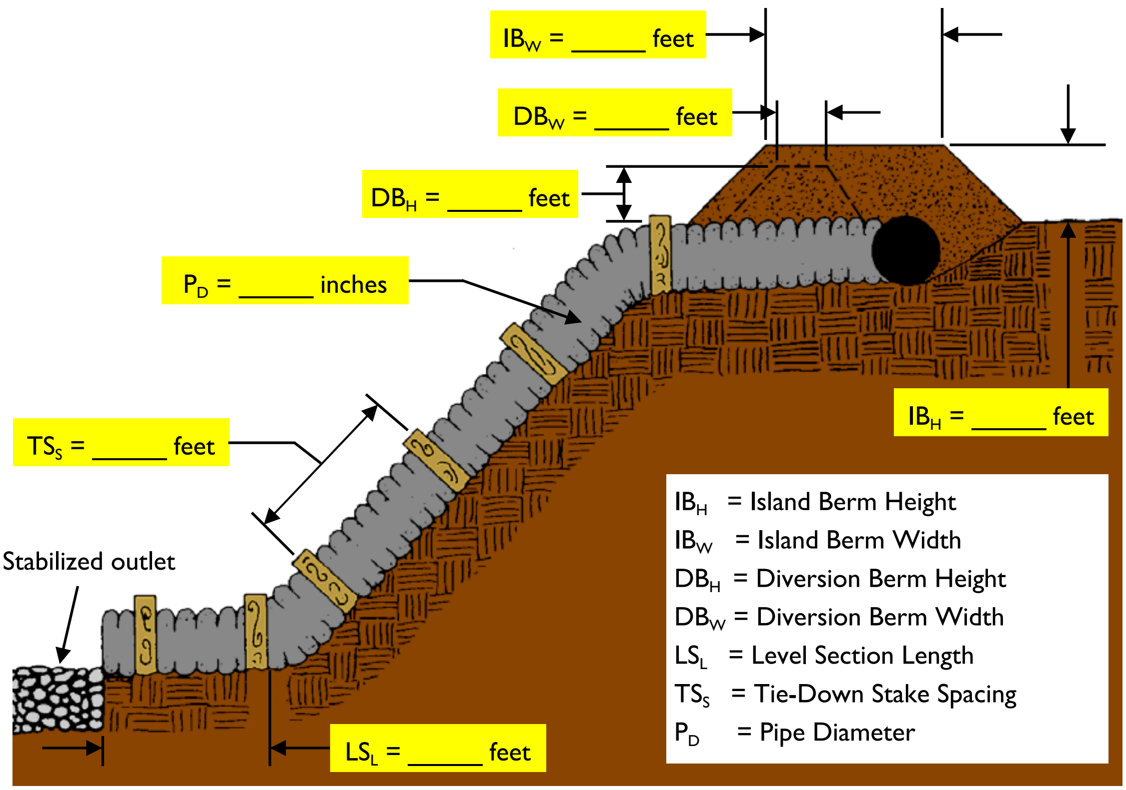
Maintenance

- Inspect within 24 hours of each rain event and at least once every seven calendar days.
- 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 pipe 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 temporary diversions and slope drains, and stabilize all disturbed areas.

Exhibit 1


Diversion berm
Diversion channel
Anchor stake spacing
(maximum of 10 feet)
Flow
Corrugated, non-perforated
plastic drain pipe
Anchor stakes
Stabilized outlet
Level section
(4 foot min.)
Earthen island over
inlet section of drain

Temporary Slope Drain Worksheet



Note: For minimum and maximum dimensions see the "Specifications" section of this measure.)

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

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RUNOFF CONVEYANCE SYSTEMS

Runoff conveyance systems are measures that have been designed to carry concentrated runoff from small areas to a stable outlet without causing erosion in the conveyance system and erosion/damage at the outlet. Measures in this section primarily include channels and swales. These conveyance systems are usually stabilized with vegetation or some type of hard armor. Conveyance systems should be constructed and stabilized prior to becoming functional. Every effort should be made to prevent sediment from entering the conveyance system, especially after it becomes functional.

Designs for runoff control measures can be complex and generally require detailed site investigations and the application of sound engineering principles. A professional knowledgeable of the principles of storm water management and experienced in structural design should be consulted when using runoff control measures.

Grass-Lined Channel

*A **grass-lined channel** is a storm water conveyance measure consisting of a natural channel or constructed channel, shaped, and graded to required dimensions, stabilized with suitable vegetation, and used to convey water in a non-erosive manner.*

Purpose

To carry concentrated storm water runoff from a small watershed area to a stable outlet without damage from erosion.

Specifications

Minimum Capacity

Peak runoff from 10-year frequency, 24-hour duration storm event.

Channel

Design based on contributing drainage area.

- Size – as specified in the construction plans (a 3:1 ratio of bottom width to depth is recommended for maximum storm water pollutant removal).
- Grade – as specified in the construction plans (generally restricted to a gradient of five percent or less).
- Cross Section – parabolic or trapezoidal.
- Side Slopes – 3:1 ratio or flatter to establish and maintain vegetation and facilitate mowing.

Channel Stabilization

Stabilize channel with one or more of the following measures; select based on field conditions and channel velocity.

- Erosion control blankets.
- Turf reinforcement mats.
- Sod.

Outlet

Stable.

Materials

- Erosion control blankets, turf reinforcement mats, or sod (optional).
- Drainage tile – used in areas with a seasonal high water table or seepage problems.
  - Offset from center of channel.
  - Minimum of two feet of soil cover over the tile.
  - Animal guard placed on pipe outlet section (as needed).

Installation

1. Remove and properly dispose of brush, trees, and other debris from the foundation area.

2. Excavate and shape the channel to lines and dimensions shown on construction plans, removing and properly disposing of excess soil so that surface water can enter the channel freely.

3. If soils have a seasonal high water table, install subsurface drainage tile. Offset the drainage tile to one side of the channel (do not place in the center of the channel). Utility lines should not be installed near the channel bottom. Protect all concentrated inflow points along the channel with erosion-resistant linings such as riprap or with other appropriate measures.

4. Add topsoil where soils exposed during excavation would be unsuitable for establishment of vegetation.

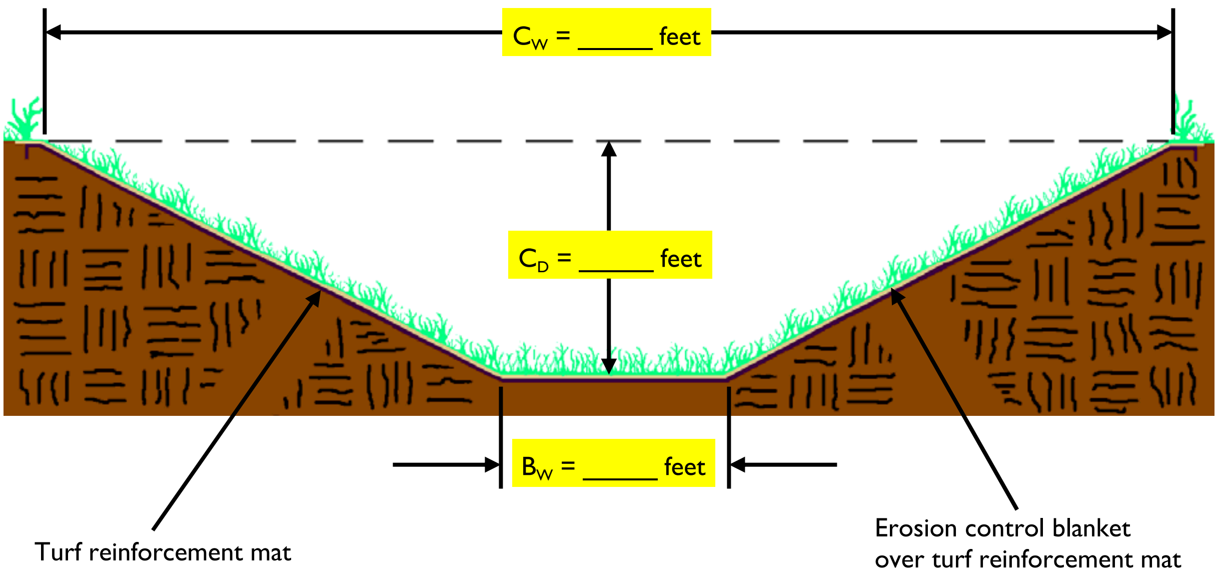
5. Seed (see **Permanent Seeding** on page 35) channel immediately after grading and protect with erosion control blankets (see **Erosion Control Blanket** on page 63), turf reinforcement mats (see **Turf Reinforcement Mat** on page 65), or install sod (see **Sod** on page 47).

6. Stabilize outlets during channel installation (see the **Outlet Protection and Grade Stabilization** measures on pages 119–142).

Maintenance

- Inspect within 24 hours of each rain event and at least once every seven calendar days.
- Check 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 channel to maintain design cross section and channel grade and to prevent spot erosion.

Grass-Lined Channel Worksheet



B_W = Designed Bottom Width of Channel

C_W = Designed Top Width of Channel

C_D = Designed Depth of Channel

Riprap-Lined Chanel

*A **riprap-lined channel** is a storm water conveyance measure consisting of a natural channel or constructed channel, shaped, and graded to required dimensions, stabilized with riprap, and used to convey water in a non-erosive manner.*

Purpose

To carry concentrated storm water runoff from a small watershed area to a stable outlet without damage from erosion.

Specifications

Note: **Designed by a qualified individual/professional engineer. Additional design considerations will be required when discharge velocities are very high or tailwater conditions are very low.**

Minimum capacity

Peak runoff from 10-year frequency, 24-hour duration storm event.

Foundation

Stable, relatively homogeneous, mineral soil with low piping potential.

Channel

Design based on contributing drainage area.

- Size – as specified in the construction plans.
- Grade – as specified in the construction plans (generally restricted to a gradient of five percent or less).
- Cross Section – parabolic or trapezoidal.
- Side Slopes – 2:1 ratio or flatter.

Thickness of Riprap Layer

Two times designed d_{50} (see Appendix A – Glossary of Terms) stone diameter or 12 inches, whichever is greater.

Outlet

Stable.

Materials

- Riprap
  - Hard, angular, highly weather resistant.
  - Specific gravity of at least 2.5.
  - Size and gradation that will withstand velocities of channel flow design. (Do not use broken concrete.)
  - Well-graded mixture of stone with 50 percent of the stone pieces, by weight, larger than the designed d_{50} size.
  - No more than 15 percent of the pieces, by weight, should be less than three inches.
- Geotextile fabric or well-graded aggregate [INDOT CA No. 9, 11, or 12 (see Appendix D)].
- Concrete grout (optional).
- Drainage tile
  - Used in areas with a seasonal high water table or seepage problems.
  - Offset from center of channel.
  - Minimum of two feet of soil cover over the tile.
  - Animal guard placed on pipe outlet section (as needed).

Installation

1. Remove and properly dispose of brush, trees, and other debris from the foundation area.

2. Excavate foundation subgrades below design elevation to allow for thickness of the filter medium (geotextile fabric or well-graded aggregate) and riprap (see Riprap-Lined Channel Worksheet on page 118).

   Note: **This overcut significantly increases excavation and spoil disposal. For instance, for the channel on the Riprap-Lined Channel Worksheet, excavation doubles from 1.1 cubic yards per foot of**

channel to 2.2 cubic yards per foot. An aggregate filter medium would require even more excavation and disposal.

3. Smooth the subgrade enough to protect geotextile fabric from tearing.

4. Place geotextile fabric or aggregate filter medium (for stabilization and filtration) on the compacted and smoothed foundation. If more than one piece of geotextile fabric is needed, the upstream piece should overlap the downstream piece by at least 12 inches.

5. Install riprap to the lines and elevations shown in the construction plans. If the channel is poorly defined, the final cross section should be nearly level with the middle slightly depressed or lower than the outer edges. If the channel is well defined, the filter medium and riprap should extend to the top of the channel banks. The riprap 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 stone sizes.

6. If geotextile fabric tears when placing riprap, repair immediately by laying and stapling a piece of fabric over damaged area, overlapping the undamaged areas by at least 12 inches.

7. Blend riprap smoothly to surrounding grade, avoiding overfill or channel constriction.

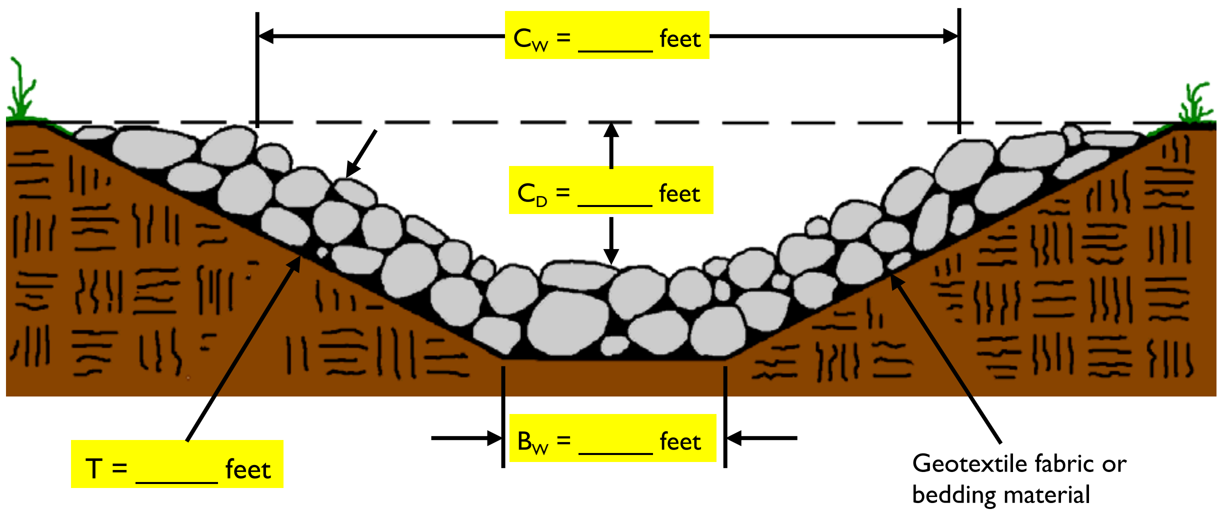
   Note: **Grass-lined channels with riprap bottoms must have a smooth transition between the riprap and vegetation.**

8. Stabilize channel inlet points and install needed outlet protection during channel stabilization.

Maintenance

- Inspect within 24 hours of each rain event and at least once every seven calendar days.
- When stones have been displaced, remove debris and replace stones in such a way as to not restrict the flow area.
- If filter fabric is damaged, remove the riprap and repair by adding another layer of fabric, overlapping adjacent, undamaged areas by 12 inches. Secure fabric with anchor pins spaced every three feet, then replace riprap.
- 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.

Riprap-Lined Channel Worksheet



B_W = Designed Bottom Width of Channel

C_W = Designed Top Width of Channel

C_D = Designed Depth of Channel

T = Thickness of Riprap

OUTLET PROTECTION & GRADE STABILIZATION

When concentrated runoff is carried through a storm water conveyance system and discharged, it is necessary to provide a stable outlet. Outlet protection measures listed in this section are designed to prevent scouring at the point of discharge and provide energy dissipation to reduce erosion downstream of the discharge.

The measures listed in this section are designed to:

- Establish a stable grade and prevent erosion and head cutting at the outlet of a conveyance channel; or
- Establish an in-channel, stable grade transition and provide for flatter channel grade in the upper and lower reaches of the conveyance channel, thereby reducing flow velocity and reducing potential for in-channel erosion and head cutting at the point of transition.

Designs for outlet protection and grade stabilization structures can be complex and generally require detailed site investigations and the application of sound engineering principles. A professional knowledgeable of the principles of storm water management and experienced in structural design should be consulted when using these structures.

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Energy Dissipater (Outlet Protection)

An ***energy dissipater (outlet protection)*** *is an erosion control measure consisting of riprap placed at the outlet end of culverts, conduits, channels, etc.*

Purpose

To prevent erosion at the outlet of a channel or conduit by reducing the velocity of storm water flow and dissipating its energy.

Specifications

Note: **Designed by a qualified individual/professional engineer. Additional design considerations will be required when discharge velocities are very high or tailwater conditions are very low.**

Capacity:

Peak runoff from a 10-year frequency, 24-hour storm event or the design discharge of the water conveyance structure, whichever is greater.

Maximum Velocity

Ten feet per second.

Tailwater Depth

- Determined immediately below the structure outlet.
- Based on design discharge plus other contributing flows.

Apron

- Length and width determined according to tailwater conditions.

- Aligned straight with channel flow. If a curve is necessary to align the apron with the receiving stream, locate the curve in the upstream section of the apron.
- Plunge pool (used with higher velocity flows).
- Thickness
  - 1.2 times the maximum stone diameter for a d_{50} stone size of 15 inches or larger.
  - 1.5 times the maximum stone diameter for a d_{50} stone size of 15 inches or less.

Table 1. Sizing for Flow Dissipaters at Culvert Pipe Outlets[1]

Pipe Size	Average Riprap Diameter	Apron Width[2]	Apron Length[3]
8 in.	3 in.	2 to 3 ft.	5 to 7 ft.
12 in.	5 in.	3 to 4 ft.	6 to 12 ft.
18 in.	8 in.	4 to 6 ft.	8 to 18 ft.
24 in.	10 in.	6 to 8 ft.	12 to 22 ft.
30 in.	12 in.	8 to 10 ft.	14 to 28 ft.
36 in.	14 in.	10 to 12 ft.	16 to 32 ft.

[1] For larger or higher flows consult a registered engineer.

[2] Apron width at the narrow end of apron (pipe or channel outlet).

[3] Select length taking into consideration the low flow (no pressure head) or high flow (pressure head) conditions of the culvert pipe.

Materials

- Riprap
  - Hard, angular, highly weather resistant.
  - Specific gravity of at least 2.5.
  - Size and gradation that will withstand velocities of storm water discharge flow design.
  - Well-graded mixture of stone with 50 percent of the stone pieces, by weight, larger than the d_{50} size and the diameter of the largest stone equal to 1.5 times the d_{50} size.

Note: **Concrete, gabion baskets, grouted riprap, interlocking concrete blocks, cabled concrete, and turf reinforcement products are alternative options to riprap.**

- Geotextile fabric or well-graded aggregate [INDOT CA No. 9, 11, or 12 (see Appendix D)].

Installation

1. Divert surface water runoff around the structure during construction so that the site can be properly dewatered for foundation preparation.

2. Excavate foundation and apron area subgrades below design elevation to allow for thickness of the filter medium and riprap.

3. Compact any fill used in subgrade preparation to the density of surrounding undisturbed soil material.

4. Smooth subgrade enough to protect geotextile fabric from tearing.

5. Place geotextile fabric or aggregate bedding material (for stabilization and filtration) on the compacted and smoothed foundation.

6. Install riprap to the lines and elevations shown in the construction plans. Blend riprap smoothly to surrounding grade. If the channel is well defined, extend the apron across the channel bottom and up the channel banks to an elevation of six inches above the maximum tailwater depth or to the top of the bank, whichever is less.

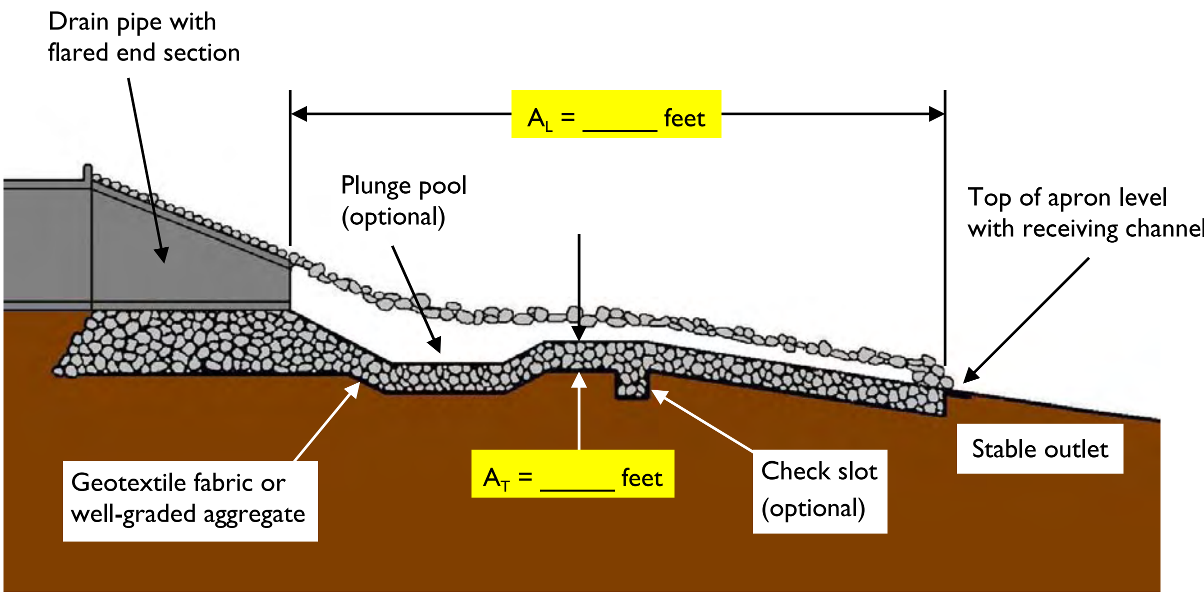
7. If geotextile fabric tears when placing riprap, repair immediately by laying and stapling a piece of fabric over damaged area, overlapping the undamaged areas by at least 12 inches.

8. Construct a small plunge pool within the outlet apron. (Riprap aprons must be level with or slightly lower than the receiving channel and should not produce an overfall or restrict flow of the water conveyance structure.)

Maintenance

- Inspect within 24 hours of a rain event and at least once every seven calendar days.
- Inspect for stone displacement; replace stones ensuring placement at finished grade.
- Check for erosion or scouring around sides of the apron; repair immediately.
- Check for piping or undercutting; repair immediately.

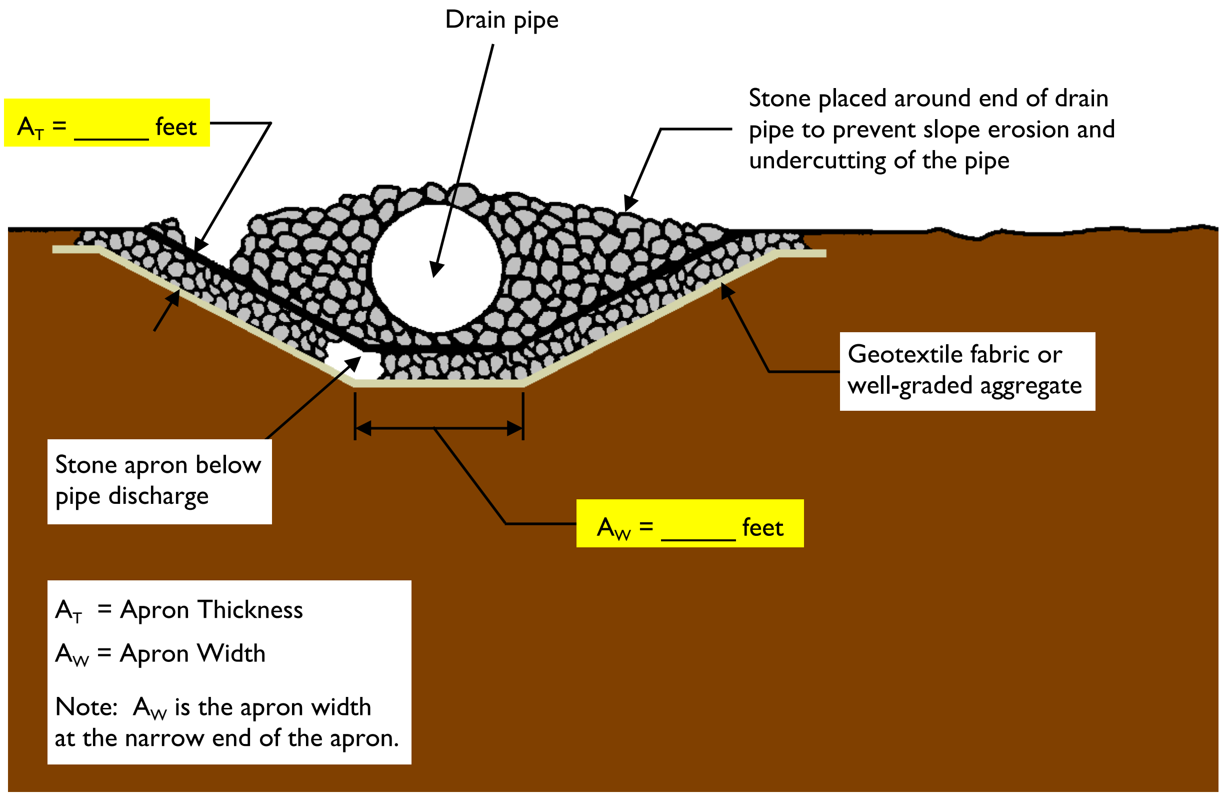
Energy Dissipater Worksheet 1



A_L = Apron Length

A_T = Apron Thickness

Energy Dissipater Worksheet 2



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Rock-Lined Chute

*A **rock-lined chute** is a storm water conveyance measure, consisting of a defined channel lined with riprap, that is used to convey water down a steep grade in a non-erosive manner.*

Purpose

- To establish a stable grade and prevent erosion and head cutting at the outlet of a conveyance channel.
- To establish an in-channel, stable grade transition and provide for flatter channel grade in the upper and lower reaches of the conveyance channel, thereby reducing flow velocity and reducing potential for in-channel erosion and head cutting at the point of transition.

Specifications

Contributing Drainage Area

50 acres maximum (designed by a qualified individual/professional engineer; larger watersheds may be accommodated but may require additional design considerations).

Capacity

Peak runoff from 10-year frequency, 24-hour storm event.

Foundation

Stable, relatively homogeneous, mineral soil with low piping potential.

Diversion Ridge

- Designed and constructed to channel surface water runoff into the concrete block chute.

- Side slopes – 2:1 ratio or flatter.
- Top width – four foot minimum.

Inlet and Outlet Aprons

- Excavated below design elevation to allow for thickness of filter medium and riprap.
- Aligned straight with channel flow.
- Set at zero grade.
- Transition section consisting of properly sized riprap at the toe of the structure to prevent erosion of the outlet and the channel bed.
- Plunge pool constructed in the outlet apron.

Thickness of Riprap Layer

Two times the d_{50} stone diameter or 12 inches, whichever is greater.

Materials

- Riprap
  - Hard, angular, highly weather resistant.
  - Specific gravity of at least 2.5.
  - Size and gradation that will withstand velocities of channel flow design.
  - Well-graded mixture of stone with 50 percent of the stone pieces, by weight, larger than the d_{50} size and the diameter of the largest stone equal to 1.5 times the d_{50} size.
- Geotextile fabric or well-graded aggregate [INDOT CA No. 9, 11, or 12 (see Appendix D)].
- Concrete grout (optional).
- Drainage tile
  - To prevent seepage of up-slope groundwater.
  - Offset from center of channel.
  - Minimum of two feet of soil cover over the tile.
  - Animal guard placed on pipe outlet section (as needed).

Installation

1. Divert surface water runoff around the structure during construction so that the site can be properly dewatered for foundation preparation, construction of headwalls, apron drains, and other structural appurtenances.

2. Excavate foundation and apron subgrades below design elevation to allow for thickness of the filter medium and riprap.

3. Compact any fill used in subgrade preparation to the density of the surrounding undisturbed soil material.

4. Smooth the subgrade enough to protect geotextile fabric from tearing.

5. Place geotextile fabric or aggregate bedding material (for stabilization and filtration) on the compacted and smoothed foundation. If more than one piece of geotextile fabric is needed, the upstream piece should overlap the downstream piece by at least 12 inches.

6. Install riprap to the lines and elevations shown in the construction plans. If the channel is poorly defined, the final cross section should be nearly level with the middle, slightly depressed or lower than the outer edges of the chute. If the channel is well defined, the filter medium and riprap should extend to the top of the channel banks.

7. 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 inches.

8. Blend riprap smoothly to the surrounding grade.

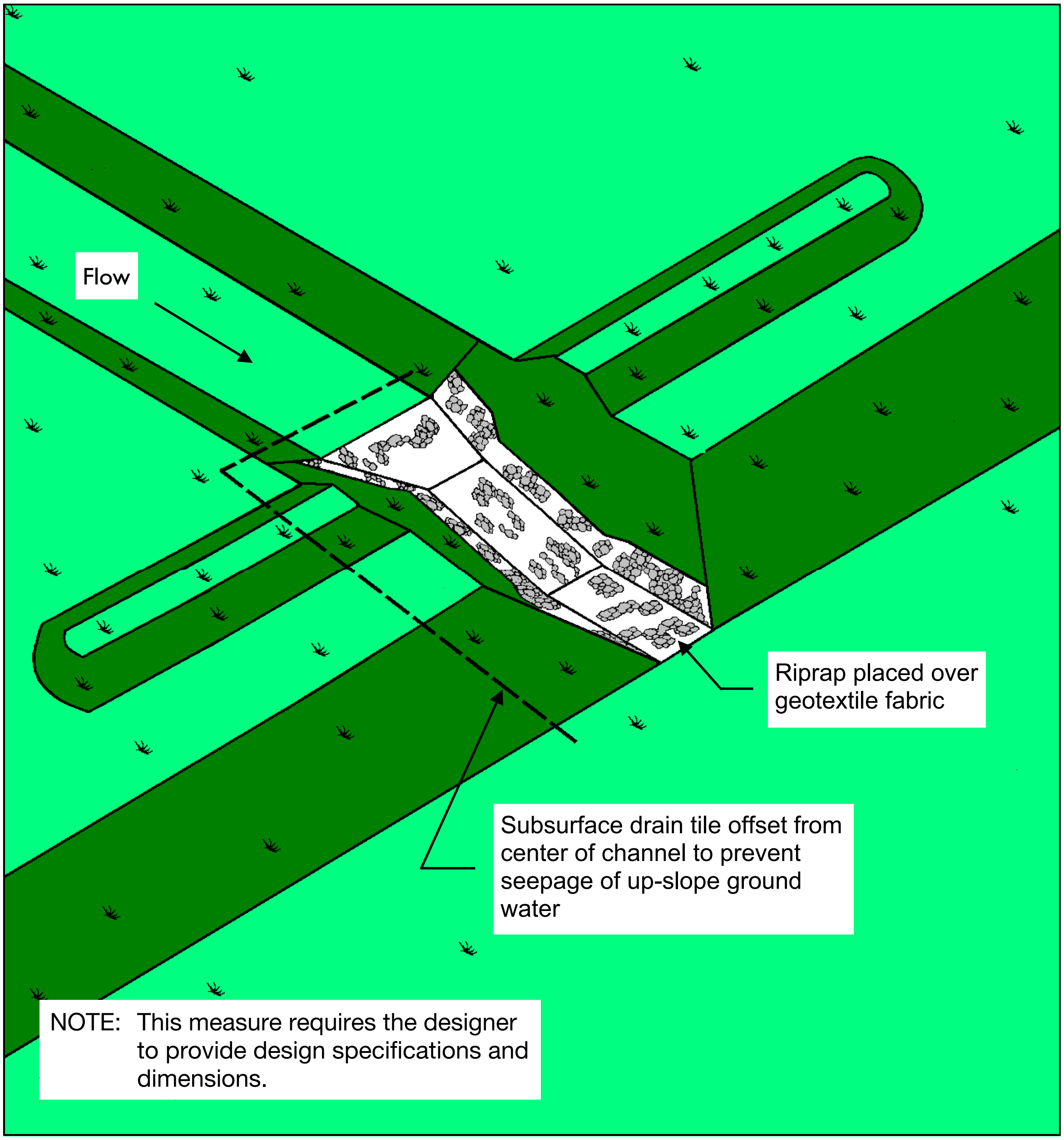
9. Construct a small plunge pool within the outlet apron. Riprap aprons must be level with or slightly lower than the channel grade and should not restrict channel flow or produce an overfall.

10. Construct a permanent diversion ridge (see **Permanent Diversion** on page 79), according to design capacity, on each side of the riprap-lined chute to collect storm water runoff and direct its flow into the chute.

Maintenance

- Inspect within 24 hours of a rain event and at least once every seven calendar days.
- Inspect riprap-lined chutes for stone displacement, erosion along sides of chute, scouring around aprons, and piping or undercutting; make needed repairs immediately, using appropriate size stone and ensuring placement at finished grade.

Exhibit 1



Source: Adapted from U.S. Department of Agriculture, Natural Resources Conservation Service

Concrete Block Chute

*A **concrete block chute** is a storm water conveyance measure, consisting of a defined channel lined with standard concrete blocks, that is used to convey water down a steep grade in a non-erosive manner.*

Purpose

- To establish a stable grade and prevent erosion and head cutting at the outlet of a conveyance channel.
- To establish an in-channel, stable grade transition and provide for flatter channel grade in the upper and lower reaches of the conveyance channel, thereby reducing flow velocity and reducing potential for in-channel erosion and head cutting at the point of transition.

Specifications

Contributing Drainage Area

50 acres maximum (designed by a qualified individual/professional engineer; larger drainage areas may be accommodated, but may require additional design considerations).

Capacity

Runoff from a 10-year frequency, 24-hour storm event.

Maximum Overfall

Ten feet.

Diversion Ridge:

- Designed and constructed to channel surface water runoff into the concrete block chute.

- Side slopes – 2:1 ratio or flatter.
- Top width – four foot minimum.

Chute Foundation:

- Chute-bottom and side-slope subgrade excavated and/or filled and compacted to approximately 10 inches below finished grade.
- Subgrade overlain with plastic sheeting or geotextile fabric, covered with two inches of bedding aggregate (INDOT CA No. 9, 11, or 12), and finally covered with geotextile fabric.

Inlet and Outlet Aprons:

- Excavated 10 inches below finished grade.
- Aligned straight with channel flow.
- Set at zero grade

Materials:

- Standard eight-inch concrete blocks.
- INDOT CA No. 9, 11, or 12 aggregate (see Appendix D).
- Plastic sheeting (4 mm or thicker).
- Geotextile fabric (for stabilization and filtration).
- Drainage tile
  - To prevent seepage of up-slope groundwater.
  - Offset from center of channel.
  - Minimum of two feet of soil cover over the tile.
  - Animal guard placed on pipe outlet section (as needed).

Installation

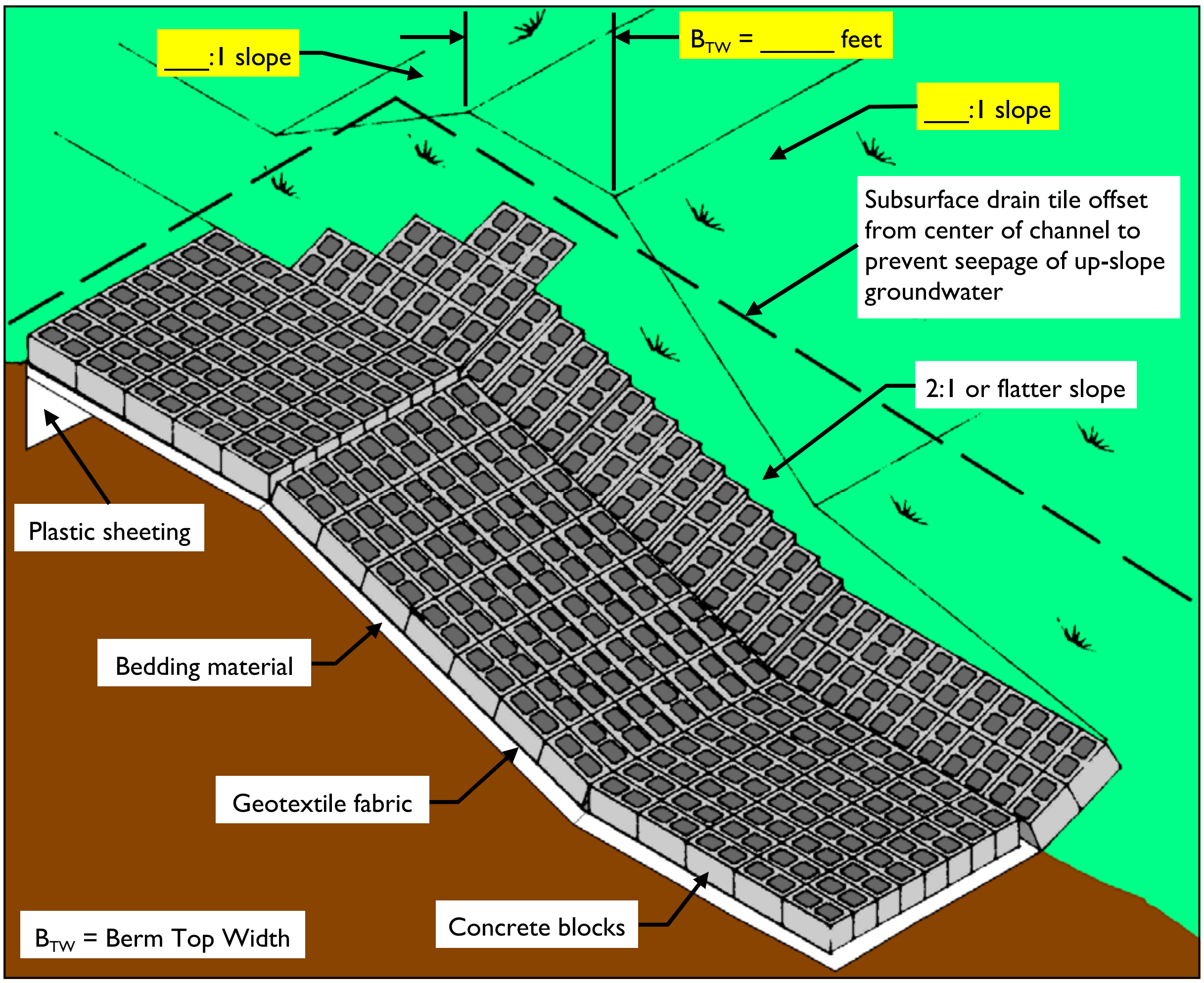
1. Divert surface water runoff around the structure during construction so that the site can be properly dewatered for foundation preparation, construction of headwalls, apron drains, and other structural appurtenances.
2. Excavate foundation subgrade for the chute and inlet and outlet aprons to about 10 inches below finished grade elevations (to allow for thickness of bedding materials and the concrete blocks). Align the aprons with channel flow and install them on zero grade.
3. Compact any fill used in the subgrade to the density of the surrounding undisturbed soil material.
4. Smooth subgrade enough to protect plastic sheeting and geotextile fabric from tearing.

5. Excavate a 12-inch to 18-inch deep trench around the perimeter of the structure (e.g., edges of inlet and outlet aprons and top of the chute and chute side slopes) to entrench and secure the plastic sheeting/geotextile fabric and minimize potential for piping and undercutting.
6. Install plastic sheeting or geotextile fabric over the smoothed subgrade. If more than one sheet of plastic or geotextile fabric is needed, the upstream piece should overlap the downstream piece by at least 12 inches.
7. Place two inches of bedding aggregate over the plastic sheeting/geotextile fabric.
8. Cover the aggregate with a layer of geotextile fabric. As noted in step seven, upstream pieces of the fabric should overlap downstream pieces by at least 12 inches.
9. Construct a permanent diversion ridge (see **Permanent Diversion** on page 79), according to design capacity, on each side of the concrete block chute to collect storm water runoff and direct its flow into the chute.
10. Lay the edges of the plastic sheeting and geotextile fabric in the excavated trench so that the edges extend to the bottom of the trench with approximately four inches laying flat in the trench bottom. Using six inch or longer metal or wooden staples, anchor the sheeting and fabric in the trench, backfill with soil material, and compact.
11. Lay concrete blocks (holes facing up) on the geotextile fabric as shown in Exhibit 1, taking care not to damage the fabric. If fabric is torn when placing the blocks, repair immediately by laying and stapling a piece of fabric over the damaged area, overlapping undamaged areas by 12 inches.
12. Fill the holes in the blocks with soil and seed immediately.

Maintenance

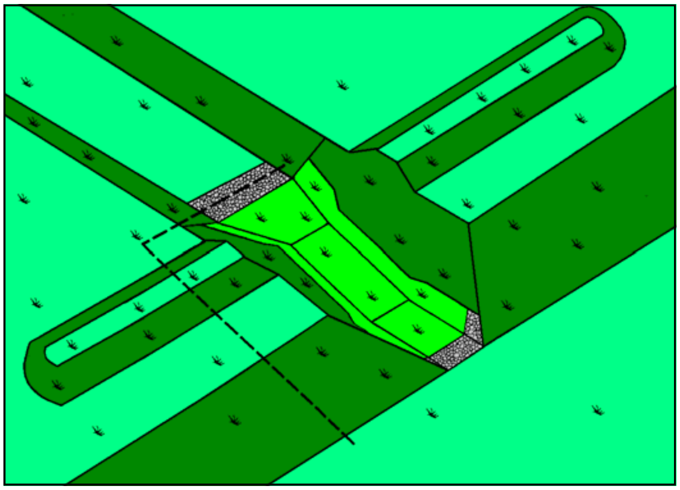
- Inspect within 24 hours of a rain event and at least once every seven calendar days.
- Inspect for scouring, piping and undercutting; make needed repairs immediately.
- Keep inlet and outlet areas free of any debris or other obstructions.
- Do not drive equipment or vehicles on the structure.

Concrete Block Chute Worksheet



Source: Adapted from USDA, Natural Resources Conservation Service

Reinforced Vegetated Chute



Source: Adapted from USDA, Natural Resources Conservation Service

A ***reinforced vegetated chute*** *is a storm water conveyance measure consisting of a defined channel lined with a three-dimensional matrix that has been filled with soil material and stabilized with vegetation. It is used to convey water down a steep grade in a nonerosive manner.*

Purpose

- To establish a stable grade and prevent erosion and head cutting at the outlet of a conveyance channel.
- To establish an in-channel, stable grade transition and provide for flatter channel grade in the upper and lower reaches of the conveyance channel, thereby reducing flow velocity and reducing potential for in-channel erosion and head cutting at the point of transition.

Specifications

Contributing Drainage Area

20 acres maximum with no base flow (designed by a qualified individual/professional engineer; larger drainage areas may be accommodated, but may require additional design considerations).

Capacity

Runoff from a two-year frequency, 24-hour storm event.

Maximum Overfall

Seven feet.

Diversion Ridge

- Designed and constructed to channel surface water runoff into the concrete block chute.
- Side slopes – 2:1 ratio or flatter.
- Top width – four foot minimum.

Materials

- Erosion control blankets.
- Turf reinforcement mats.
- Indiana Department of Transportation CA No. 5 aggregate (see Appendix D).

Note: **INDOT CA No. 8 aggregate is acceptable if No. 5 aggregate is not available.**

- Drainage tile
  - To prevent seepage of up-slope groundwater.
  - Offset from center of channel.
  - Minimum of two feet of soil cover over the tile.
  - Animal guard placed on pipe outlet section (as needed).

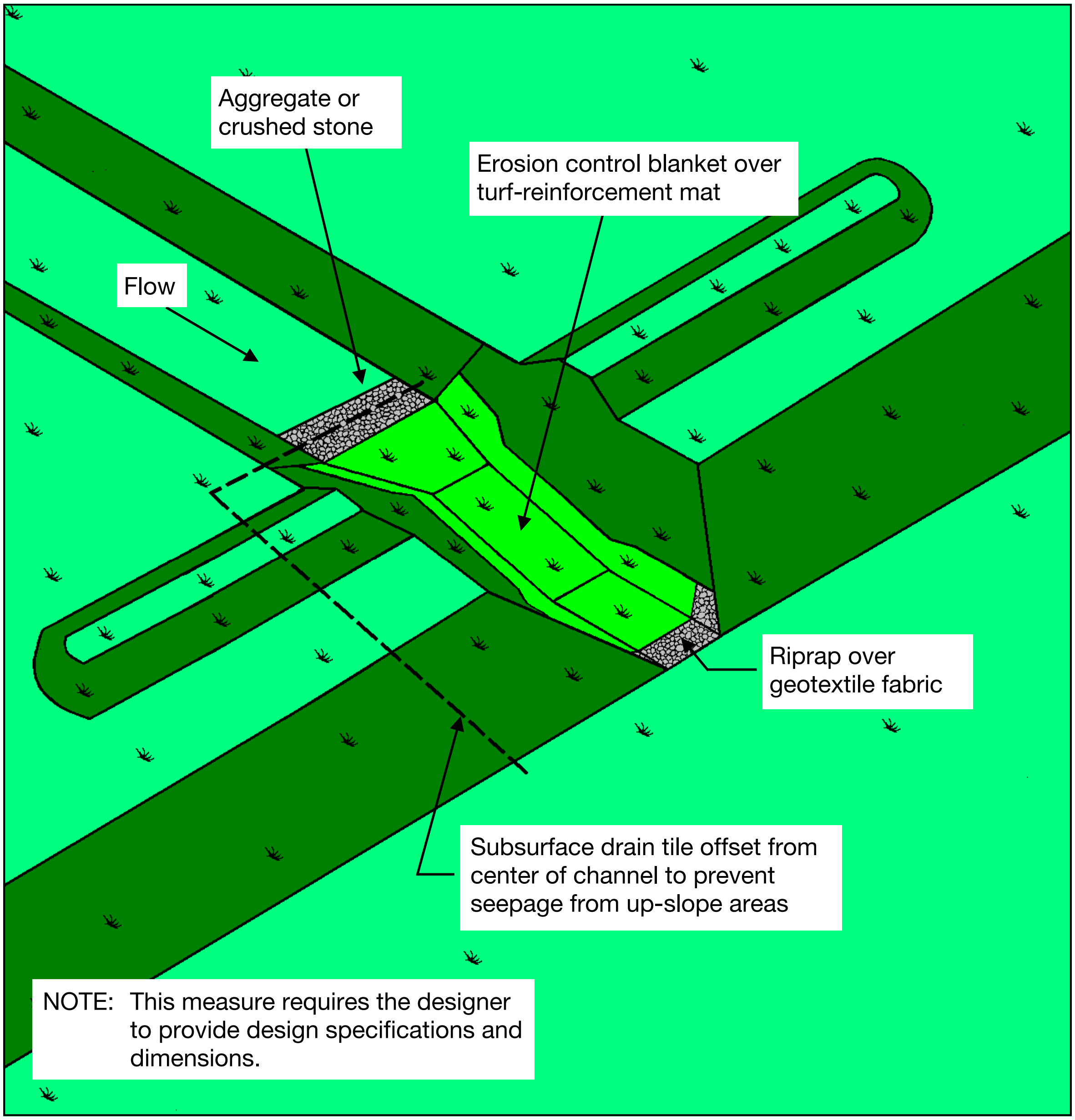
Installation

1. Excavate and/or fill and compact the chute foundation and slopes to finished grade. Excavate and/or fill and compact the apron foundations below design elevation to allow for thickness of the filter medium and aggregate. Ensure that the aprons and chute are straight and aligned with the receiving channel.
2. If needed, lay drain tile outside the chute area as shown in Exhibit 1, including outlet pipe section and animal guard.
3. Place INDOT CA No. 5 aggregate such that the inlet and outlet aprons are at zero grade. Construct a small plunge pool in the outlet apron.
4. Install and anchor the turf reinforcement mat according to manufacturer's directions and cover with soil.
5. Immediately following mat installation, permanently seed, fertilize, and install erosion control blankets (see **Erosion Control Blanket** on page 63) according to the manufacturer's directions.
6. Construct a permanent diversion ridge (see **Permanent Diversion** on page 79), according to design capacity, on each side of the reinforced vegetated chute to collect storm water runoff and direct its flow into the chute.

Maintenance

- Inspect within 24 hours of a rain event and at least once every seven calendar days.
- During vegetation establishment, inspect for blockage, sediment accumulation and scour holes.
- Remove accumulated sediment and make other repairs as necessary.

Exhibit 1



Source: Adapted from USDA, Natural Resources Conservation Service

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Pipe Drop Structure

To be released at a later time

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Toe Wall Structure

To be released at a later time

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TEMPORARY DROP INLET PROTECTION

Urban storm water management systems are efficient carriers of storm water runoff. As such, they are also efficient conduits for carrying sediment and other contaminants suspended in storm water runoff. If proper steps are not taken during the construction phase(s) of a project, these storm water management systems can carry significant amounts of sediment which can lead to siltation of the storm drain system and/or off-site sediment damage. In the worst case scenario, the storm drain system can become plugged with sediment. Cleaning the storm drain system can be extremely difficult and expensive. Therefore it is critical to keep sediment out of the storm drain system.

As was noted in the Surface Stabilization section, reducing erosion at the source is much more effective and efficient than trying to trap suspended sediment in surface water runoff. Timely installation of temporary and permanent soil stabilization measures, such as those listed in the Surface Stabilization section, can greatly reduce erosion and sediment loads and reduce frequency of maintenance operations. Unfortunately this is not always practical or possible.

When erosion cannot be controlled at the source it becomes necessary to implement sediment control measures designed to reduce the amount of sediment entering the storm drain system. The principal behind all sediment control measures is relatively simple. Slow or pond the sediment-laden surface water runoff for a sufficient length of time to allow the suspended soil particles to settle out.

Inlet protection measures should not be the only level of sediment control. It is not the intent of these measures to accommodate or be effective where sediment loading is high. It is important that appropriate sediment control measures are installed in the drainage area above the storm sewer system to reduce excessive sediment loading. The temporary drop inlet protection measures in this section are designed to reduce the amount of sediment entering a storm sewer system. It is extremely important to note that these measures require intensive maintenance and require frequent monitoring, cleanout, repair and/or replacement.

The selection of any type of inlet protection device should be selected on the principal that the storm drain inlet continues to function and carry runoff. Blocking the inlet may result in excessive or prolonged ponding/flooding. Blocking flow may also result in bypass of the storm sewer system that may redirect water to an area that results in erosion or damage to private property.

The measures illustrated in this section are a small representation of drop inlet protection devices that are available. Field modification by contractors of these measures is not uncommon and have proven to be innovative and effective. In addition, there are many types of drop inlet protection available commercially. When selecting or modifying a device it is important that the device used will allow the storm drain to function and carry runoff in the event it plugs or if an excessive storm event occurs.

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Excavated Drop Inlet Protection

***Excavated drop inlet protection** is a temporary sediment control measure consisting of an excavated area around a storm drain drop inlet.*

Purpose

To capture sediment at the approach to a storm drain inlet, allowing full use of the storm drain system during the construction period**.**

Specifications

Contributing Drainage Area

One acre maximum.

Capacity

Runoff from a two-year frequency, 24-hour storm event entering a storm drain without bypass flow.

Pool Area

- Less than one percent slope.
- Side slopes – 2:1 ratio or flatter.
- Excavated Depth – One to two feet measured from the top of the storm drain inlet.
- Storm Water/Sediment Storage Volume (excavated volume) – Minimum of 950 cubic feet.

Dewatering System

- Weep holes in the drop inlet structure.

- Geotextile fabric or hardware cloth wrapped around the sides of the drop inlet structure.
- Filter aggregate placed around the drop inlet structure.

Materials

- Geotextile fabric or hardware cloth.
- INDOT CA No. 5 aggregate (see Appendix D).

Note: **INDOT CA No. 8 aggregate is acceptable if No. 5 aggregate is not available. The use of No. 8 aggregate may result in more frequent overtopping of the structure and will increase the frequency of structure maintenance.**

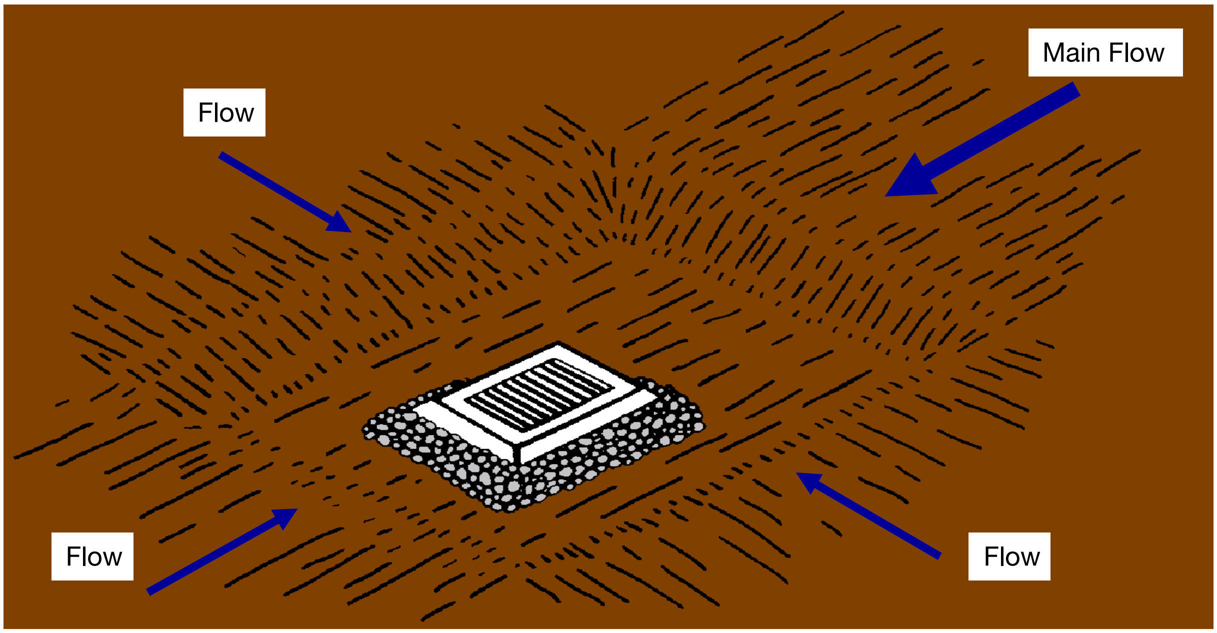
Installation

1. Clear the area of all debris.
2. Excavate the pool area with a one to two-foot depth and 2:1 side slopes or flatter. Orient the longest dimension toward the largest inflow (see Exhibit 1).
3. Stockpile or spread excavated soil so it will not block storm water flow or wash back into the excavation. If necessary, spoil may be placed to form a dike on the down-slope side of the excavation to prevent by-pass flow. The dike should be at least six inches higher than the top elevation of the storm drain inlet grate.
4. Install weep holes in the drop inlet structure so the pool drains slowly.
5. Cover the weep holes with geotextile fabric or hardware cloth and at least 12 inches of aggregate (INDOT CA No. 5) to retain the sediment (see Excavated Drop Inlet Protection Worksheet).

Maintenance

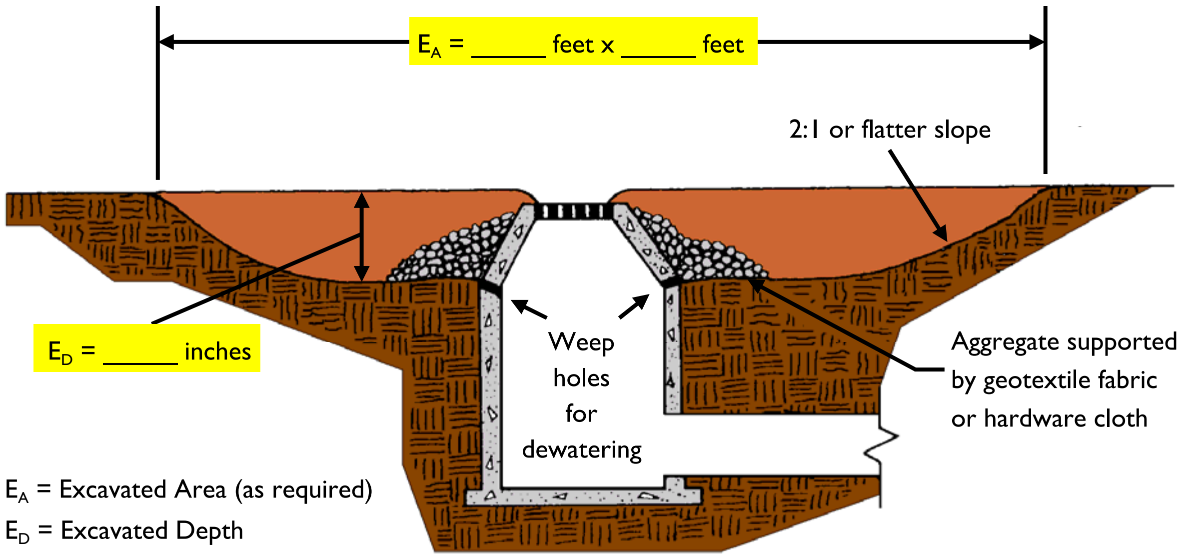
- Inspect daily.
- Remove sediment when pool area is approximately one-half full of sediment.
- Remove and replace aggregate if sediment hinders drainage.
- Once contributing drainage area has been permanently stabilized, remove sediment, seal weep holes, fill basin with soil, compact and grade to finished elevation, and stabilize.

Exhibit 1



Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

Excavated Drop Inlet Protection Worksheet



Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

Gravel Donut Drop Inlet Protection

***Gravel donut drop inlet protection** is a temporary sediment control measure consisting of an aggregate filter barrier placed around a storm drain drop inlet.*

Purpose

To trap sediment at the approach to a storm drain inlet, allowing full use of the storm drain system during the construction period.

Specifications

Contributing Drainage Area

One acre maximum.

Capacity

Runoff from a two-year frequency, 24-hour storm event entering a storm drain without bypass flow.

Aggregate Donut (see Exhibits 1 and 2)

- Side Slopes
  - 2:1 ratio or flatter on outside of aggregate donut.
  - 3:1 ratio or flatter on inside of aggregate donut.
- Height – 12 to 24 inches above the top of the storm drain inlet.

Materials

- INDOT uniform B riprap. (see Appendix D).
- INDOT CA No. 5 aggregate. (see Appendix D).

Note: INDOT CA No. 8 aggregate is acceptable if No. 5 aggregate is not available. The use of No. 8 aggregate may result in more frequent overtopping of the structure and will increase the frequency of structure maintenance.

Installation

1. Around the outer perimeter of the excavated area, lay a ring of riprap (INDOT uniform B riprap) to a height of 12 to 24 inches above the top of the storm drain inlet. Construct the aggregate donut such that it has a 2:1 or flatter outside slope and a 3:1 or flatter inside slope.

2. Cover the outside face of the aggregate donut with at least a 12-inch thick layer of INDOT CA No. 5 aggregate (for filtration). Maintain a 2:1 or flatter slope.

   Note: **In situations where storm water may bypass the structure, either:**
   - Set the top of the aggregate donut at least six inches lower than the ground elevation on the down-slope side of the storm drain inlet,
   - Build a temporary dike, compacted to six inches higher than the aggregate donut, on the down-slope side of the storm drain inlet, AND/OR
   - Use in conjunction with excavated drop inlet protection (see **Excavated Drop Inlet Protection** on page 145).

Maintenance

- Inspect daily.
- Make needed repairs immediately.
- When the contributing drainage area has been stabilized, remove and properly dispose of all sediment and construction material and restabilize.

Exhibit 1

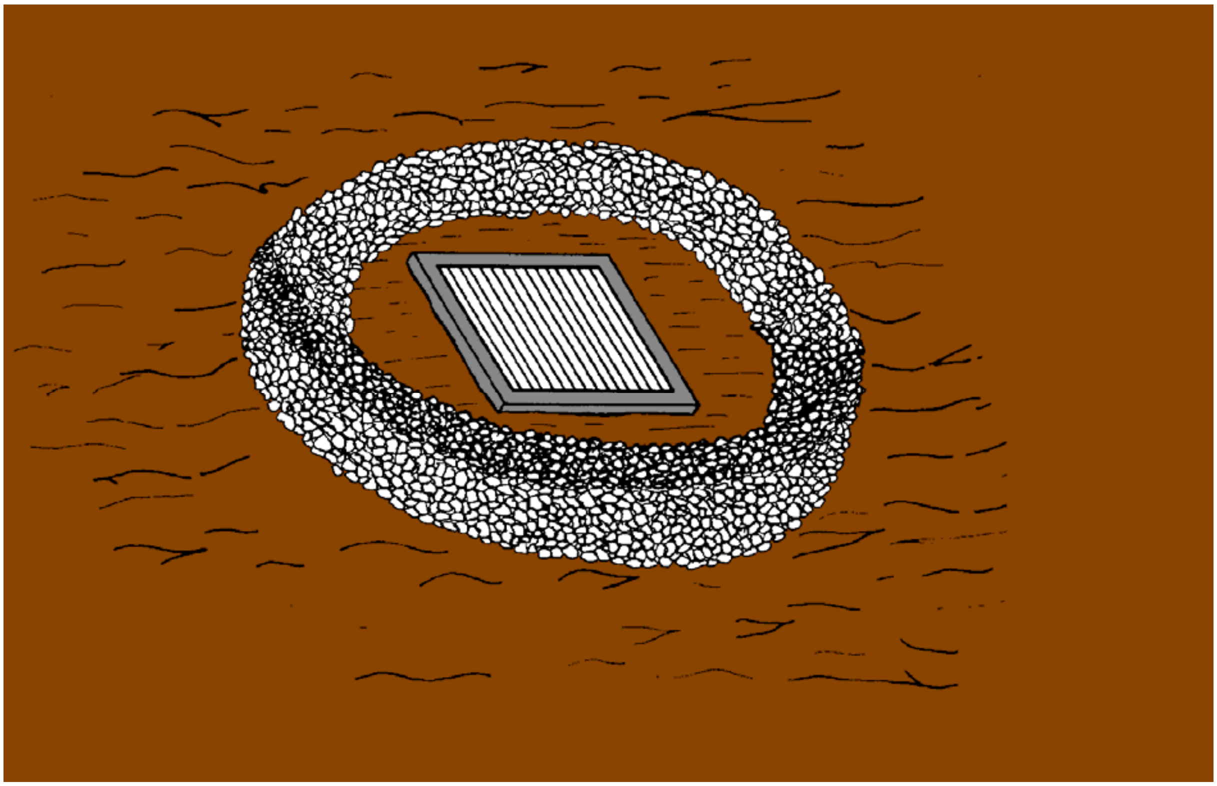
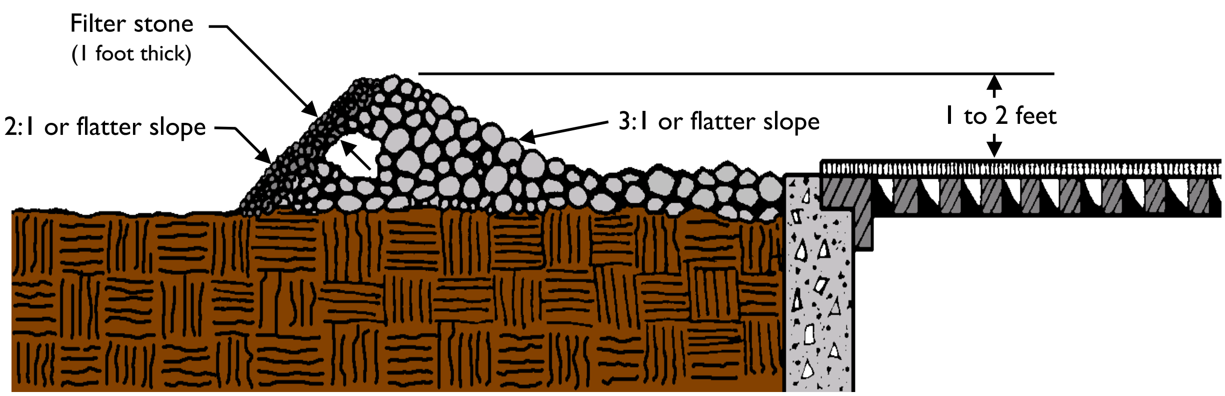


Exhibit 2



Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

Geotextile Fabric Drop Inlet Protection

Geotextile fabric drop inlet protection *is a temporary sediment control measure consisting of a temporary geotextile fabric barrier placed around a storm drain drop inlet.*

Purpose

To capture sediment at the entrance to a storm drain inlet, allowing full use of the storm drain system during the construction period.

Note: **This measure is not recommended for paved surfaces due to inability to entrench the fabric and lack of an anchoring system**.

Specifications

Note: **Alternative support systems may be substituted for hardwood posts and cross braces.**

Contributing Drainage Area

One acre maximum.

Effective Life

Six months (maximum).

Capacity

Runoff from a two-year frequency, 24-hour storm event entering a storm drain without bypass flow.

Geotextile Structure

- Height – 12 to 18 inches, measured from top of storm drain inlet.
- Post spacing – 36-inch maximum spacing between posts.
- Frame support – bracing to strengthen integrity of the structure. (Structure must withstand 1½-foot head of water and sediment without collapsing or undercutting.)

Materials

- Support posts
  - 2 x 2 inch or 2 x 4 inch hardwood posts.
  - Three feet length, minimum.
- 1 x 2 inch or 1 x 3 inch hardwood cross bracing lumber.
- Lathe.
- Staples or nails.
- Geotextile fabric

Table 1. Geotextile Fabric Specifications

Physical Property	Woven	Non-Woven
Filtering Efficiency	85%	85%
UV Resistance (Inhibitors and stabilizers to ensure six month minimum life at temperatures of 0° to 120° F)	70%	85%
Tensile Strength at 20% Elongation:		
Standard Strength	30 lbs./linear inch	50 lbs./linear inch
Extra Strength	50 lbs./linear inch	70 lbs./linear inch
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.

Installation

(see Exhibits 1 and 2)

1. Dig an eight-inch deep, four-inch wide trench around the perimeter of the inlet.
2. If using pre-assembled geotextile fabric and posts, drive the posts into the soil, tightly stretching the geotextile fabric between posts as each is driven. (Posts must be placed on the inlet side of the anchor trench with the geotextile fabric on the side of the trench farthest from the inlet.)

   Note: If assembling the geotextile fabric and posts on-site, drive the posts into the soil and then secure the geotextile fabric to the posts by placing a piece of lathe over the fabric and fastening it to the post (stretching the fabric between posts as it is fastened).

3. Use the wrap join method when joining posts (see **Silt Fence** on page 215).
4. Place the bottom 12 inches of geotextile fabric into the eight-inch deep trench, laying the remaining four inches in the bottom of the trench and extending away from the inlet.
5. Backfill the trench with soil material and compact it in place.
6. Brace the posts by nailing braces into each corner post or utilize rigid panels to support fabric.

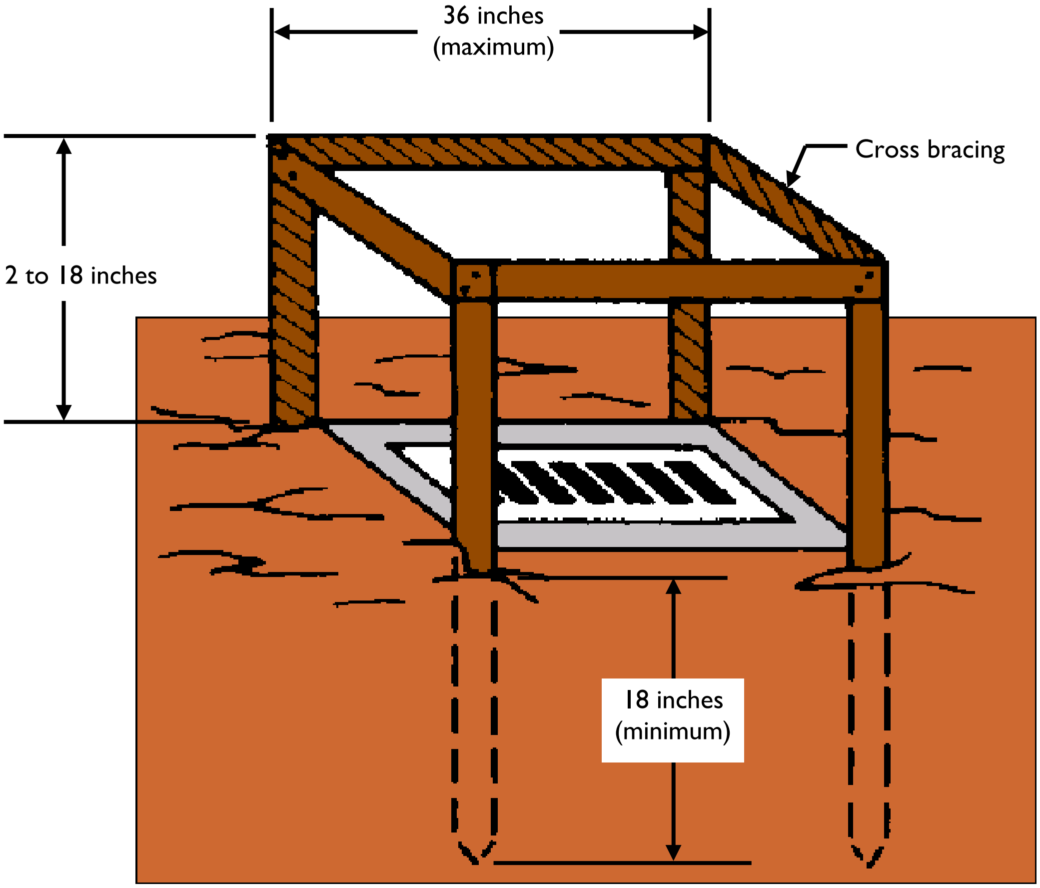
Note: **In situations where storm water may bypass the structure, either:**

- Set the top of the geotextile fabric filter at least six inches lower than the ground elevation on the down-slope side of the storm drain inlet,
- Build a temporary dike, compacted to six inches higher than the fabric, on the down-slope side of the storm drain inlet, AND/OR
- Use in conjunction with excavated drop inlet protection (see **Excavated Drop Inlet Protection** on page 145).

Maintenance

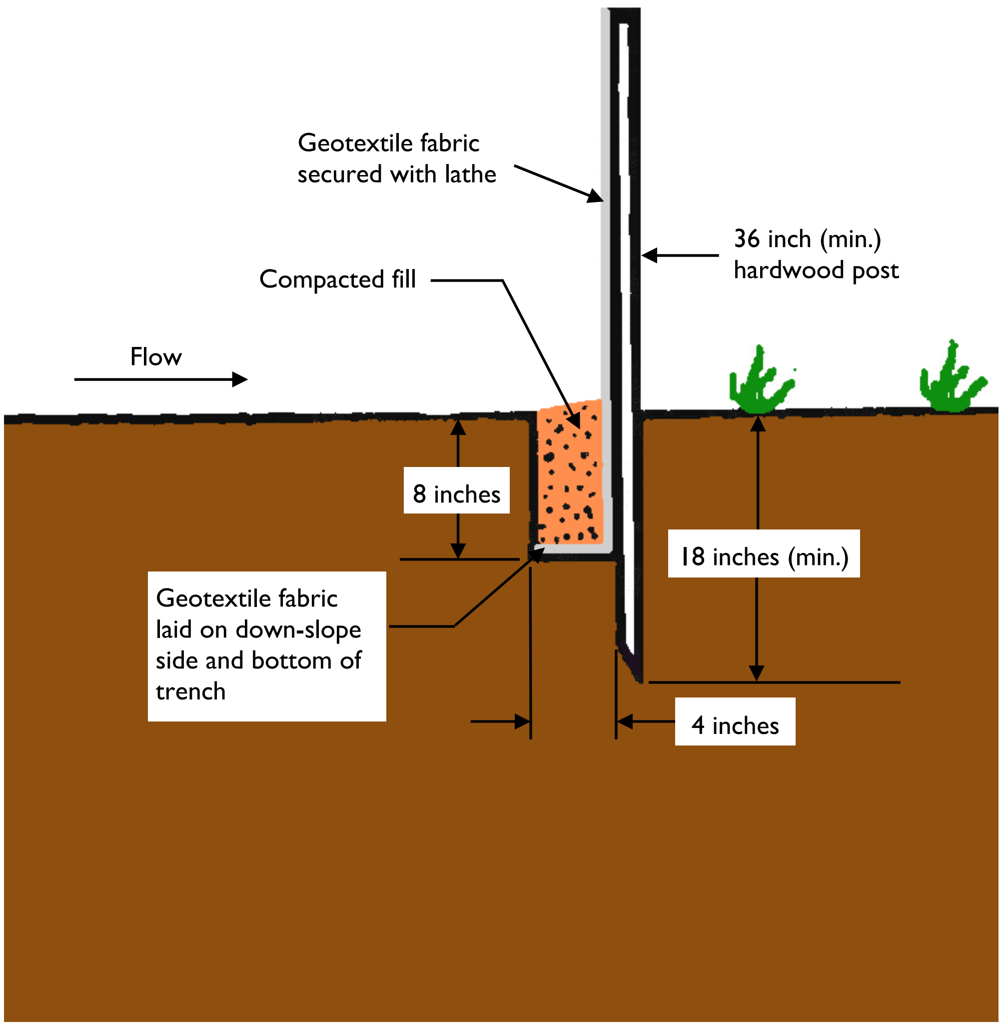
- Inspect daily.
- Inspect geotextile fabric and make needed repairs immediately.
- Remove sediment from pool area to provide storage for the next storm event. Avoid damaging or undercutting fabric during sediment removal.
- When contributing drainage area has been stabilized, remove sediment, properly dispose of all construction material, grade area to the elevation of the storm drain inlet top, then stabilize immediately.

Exhibit 1



Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

Exhibit 2


Geotextile fabric secured with lathe
36 inch (min.) hardwood post
Compacted fill
Flow
8 inches
18 inches (min.)
Geotextile fabric laid on down-slope side and bottom of trench
4 inches

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Straw Bale Drop Inlet Protection

***Straw bale drop inlet protection** is a temporary sediment control measure consisting of straw bales placed around a storm drain drop inlet.*

Purpose

To capture sediment at the inlet to a storm drain, allowing full use of the drain system during the construction period.

Note: **This measure is not recommended for paved surfaces due to inability to entrench the bales and lack of an anchoring system**.

Specifications

Contributing Drainage Area

One acre maximum.

Effective Life

Less than three months.

Capacity

Runoff from a two-year frequency, 24-hour storm event entering a storm drain without bypass flow.

Barrier Height

Fourteen inches above top elevation of the storm drain inlet.

Materials

- Straw or hay bales approximately 14 inches by 18 inches by 36 inches.
- Thirty-six inch long (minimum) steel rebar or 2 x 2 inch hardwood stakes.

Installation

(see Exhibits 1 and 2)

1. Excavate a trench at least four inches deep and a bale's width around the inlet.
2. Place bales lengthwise in the trench so the bindings are oriented around the sides, rather than top and bottom, to minimize deterioration of the bindings.
3. Allow bales to overlap at the corners, and **abut them tightly against each other** (see Exhibit 1).
4. Anchor the bales in place by driving two 36-inch long steel rebar or 2 x 2 inch 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 (see Exhibits 1 and 2).
5. Chink (tightly wedge) straw into any gaps between bales to prevent sediment-laden water from flowing between the bales and directly into the inlet.
6. Backfill excavated soil material, four inches high, against the outside perimeter of the straw bale barrier and compact in place.

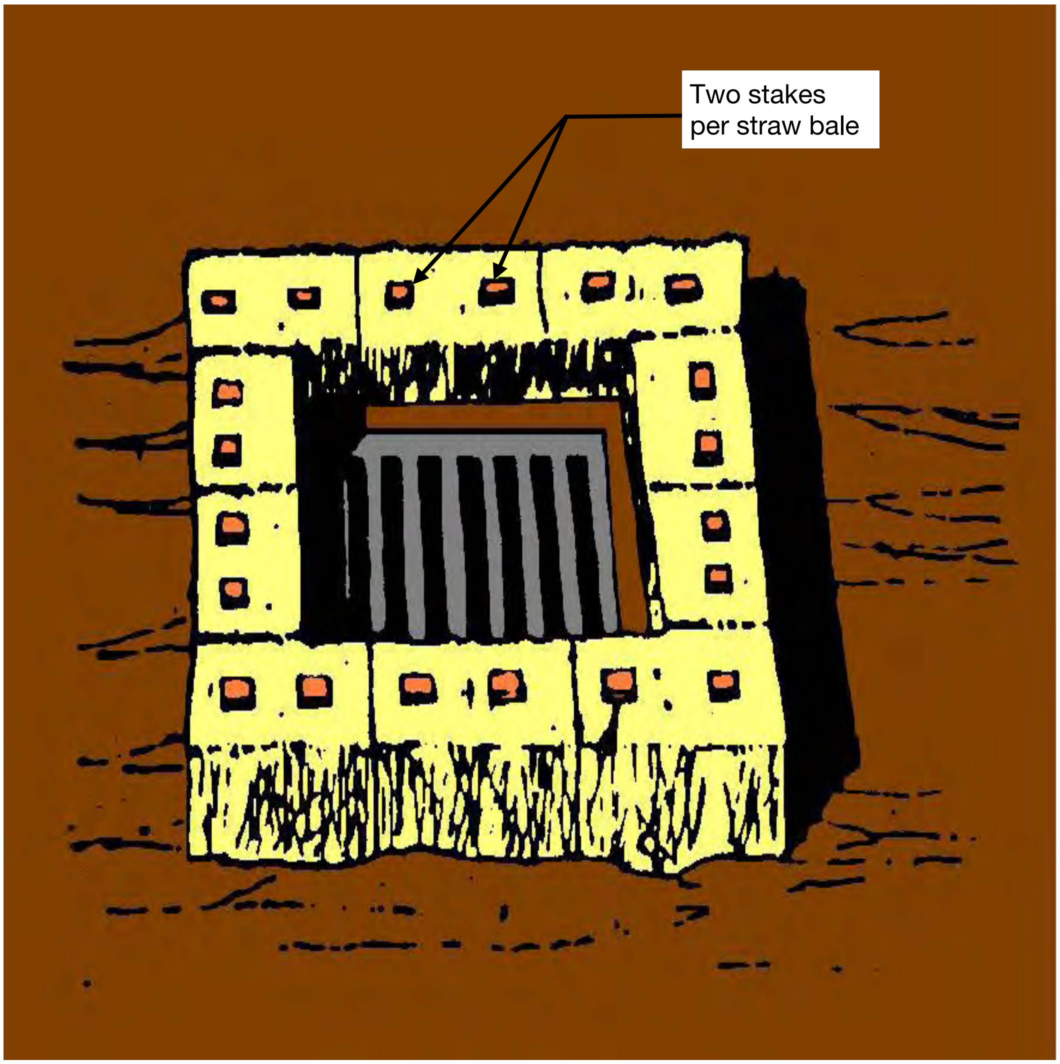
Note: **In situations where storm water may bypass the structure, either:**

- Set the top of the straw/hay bales at least six inches lower than the ground elevation on the down-slope side of the storm drain inlet,
- Build a temporary dike, compacted to six inches higher than the straw/hay bales, on the down-slope side of the storm drain inlet, AND/OR
- Use in conjunction with excavated drop inlet protection (see **Excavated Drop Inlet Protection** on page 145).

Maintenance

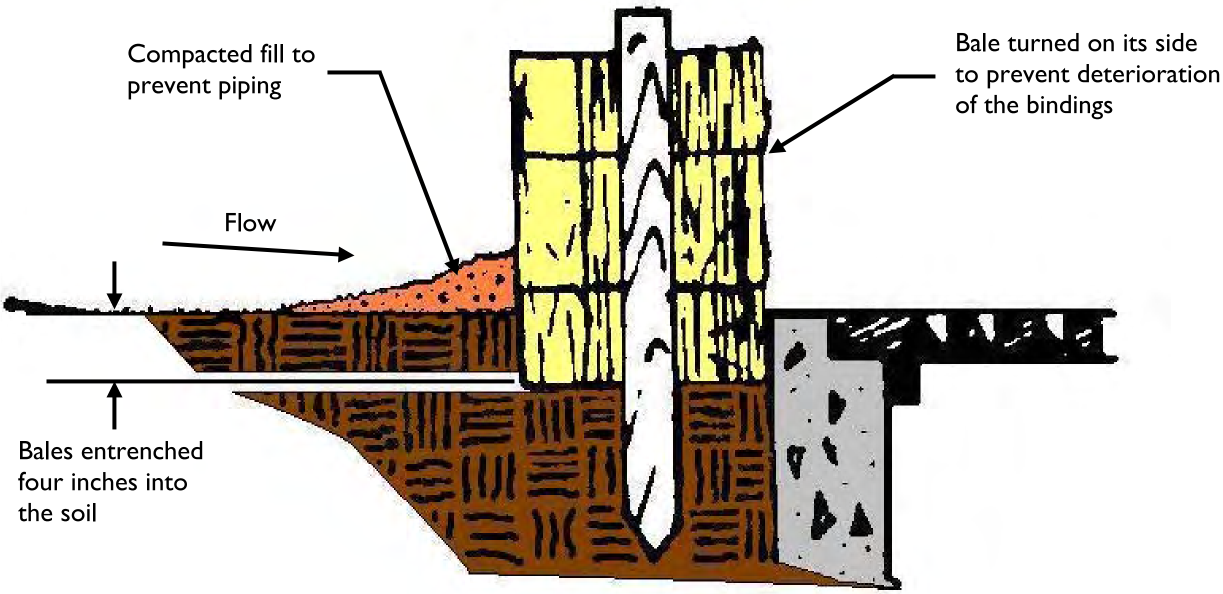
- Inspect daily.
- Remove sediment and debris from the pool area to ensure adequate storm water runoff storage from the next rain, taking care to not damage or undercut the bales.
- When the contributing drainage area has been stabilized, remove and properly dispose of accumulated sediment, all bales, and construction materials. Grade the disturbed area to the elevation of the top of the storm drain inlet and stabilize.

Exhibit 1



Source: Adapted from Michigan Soil Erosion and Sedimentation Control Guidebook, 1975

Exhibit 2



Source: Adapted from Michigan Soil Erosion and Sedimentation Control Guidebook, 1975

Block & Gravel Drop Inlet Protection

Block and gravel drop inlet protection *is a temporary sediment control measure consisting of standard concrete blocks and aggregate placed around a storm drain drop inlet.*

Purpose

To trap sediment at the approach to a storm drain inlet, allowing full use of the storm drain system during the construction period.

Specifications

Contributing Drainage Area

One acre maximum.

Capacity

Runoff from a two-year frequency, 24-hour storm event entering a storm drain without bypass flow.

Barrier Height

Two standard eight-inch concrete blocks.

Aggregate Blanket

- Side slopes – 2:1 ratio or flatter.

Sediment Dewatering Structure

- One or more concrete blocks in the bottom row placed with openings horizontal to ground surface.
- Covered with hardware cloth and aggregate to control drainage rate.

Materials

- Standard eight-inch concrete blocks.
- INDOT CA No. 5 aggregate (see Appendix D).

  Note: **INDOT CA No. 8 aggregate is acceptable if No. 5 aggregate is not available. The use of No. 8 aggregate may result in more frequent overtopping of the structure and will increase the frequency of structure maintenance.**
- Hardware cloth.

Installation

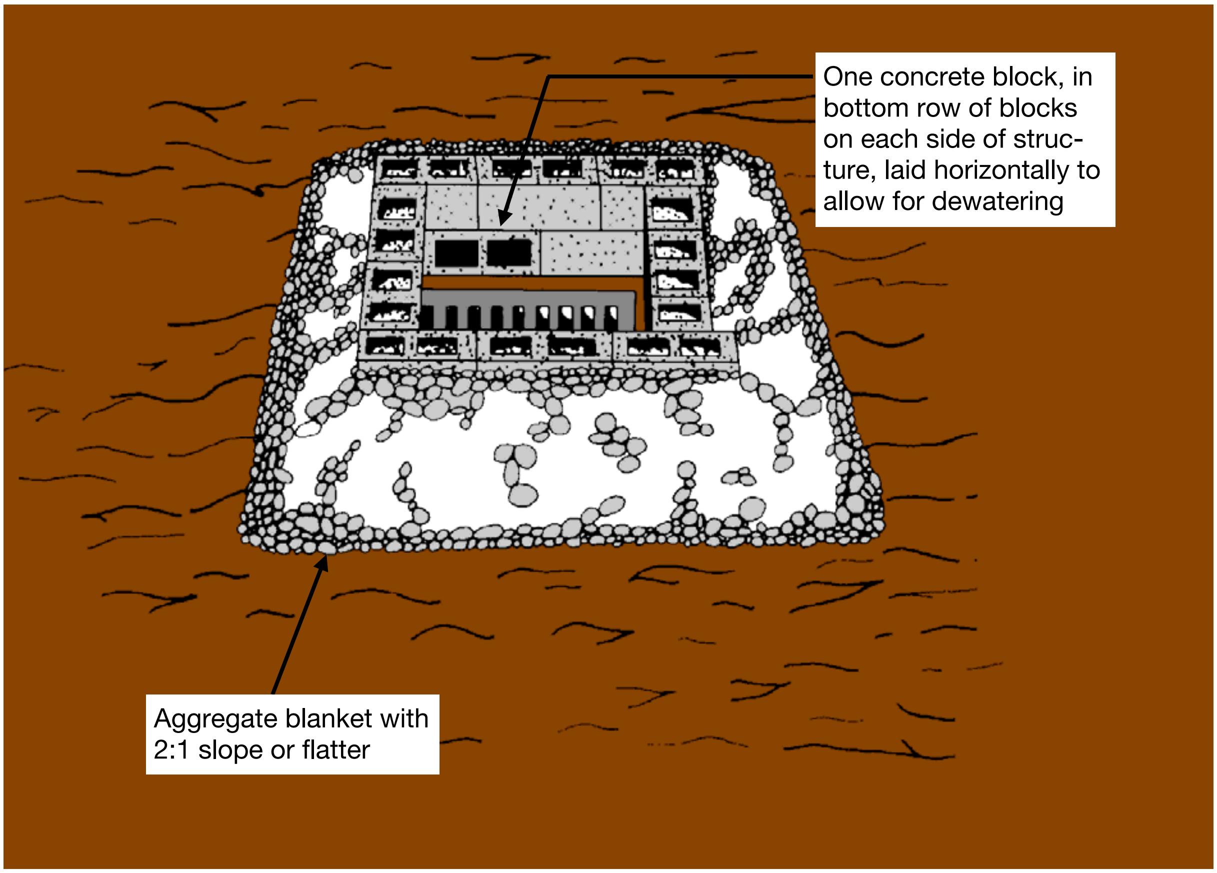
1. Excavate the foundation for the concrete blocks on level grade and at least two inches below the top of the storm drain inlet.
2. Place the bottom row of concrete blocks around the perimeter of the storm drain. Lay blocks with openings facing up, abutting the blocks firmly together and overlapping the corners (see Exhibit 1).
3. If necessary, support the blocks by driving sharpened 2 x 4 inch wood studs or rebar (not mortar) through the block openings and into the underlying soil.
4. On each side of the bottom row, turn one concrete block with its openings facing horizontally to allow for dewatering.
5. Place hardware cloth over the openings to hold the aggregate in place (see Exhibit 2).
6. Place the filter medium (INDOT CA No. 5 aggregate) around the outside of the concrete blocks to control drainage rate; limit filter medium side slopes to 2:1 ratio or flatter.

Note: **In situations where storm water may bypass the structure, either:**
- Set the top of the concrete blocks at least six inches lower than the ground elevation on the down-slope side of the storm drain inlet,
- Build a temporary dike, compacted to six inches higher than the concrete blocks, on the down-slope side of the storm drain inlet, AND/OR
- Use in conjunction with excavated drop inlet protection (see **Excavated Drop Inlet Protection** on page 145).

Maintenance

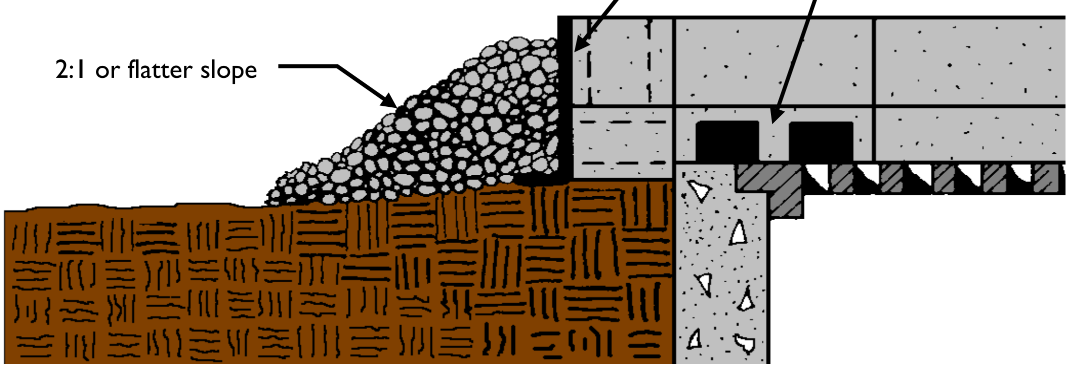
- Inspect daily.
- Remove sediment and debris and make needed repairs immediately.
- When the contributing drainage area has been stabilized, remove and properly dispose of all construction material and sediment, then stabilize.

Exhibit 1



Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

Exhibit 1



Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

TEMPORARY CURB & PAVED AREA INLET PROTECTION

Storm water management systems are efficient carriers of storm water runoff. As such, they are also efficient conduits for carrying sediment and other contaminants suspended in storm water runoff. If proper steps are not taken during the construction phase(s) of a project, these storm water management systems can carry significant amounts of sediment which can lead to siltation of the storm drain system and/or off-site sediment damage. In the worst case scenario, the storm drain system can become plugged with sediment. Cleaning the storm drain system can be extremely difficult and expensive. Therefore it is critical to keep sediment out of the system.

Reducing erosion at the source is much more effective and efficient than trying to trap suspended sediment in surface water runoff. Timely installation of temporary and permanent soil stabilization measures, such as those listed in Surface Stabilization section on pages 29–72, can greatly reduce erosion and sediment loads and reduce frequency of maintenance operations. Unfortunately, this is not always practical or possible.

When erosion cannot be controlled at the source it becomes necessary to implement sediment control measures designed to reduce the amount of sediment entering paved areas and the storm drain system. The principal behind all sediment control measures is relatively simple. Slow or pond the sediment-laden surface water runoff for a sufficient length of time to allow the suspended soil particles to settle out.

The measures in this section have been designed to reduce the amount of sediment entering a storm sewer system. These measures are intended to trap residual sediments that are either tracked or inadvertently deposited in paved areas. It is not the intent of these measures to accommodate or be effective where sediment loading is high. Every effort should be made to prevent or at the very least minimize the amount of sediment entering the paved area, either via sediment-laden surface water runoff or tracking from vehicles. Preventing sediment from entering paved areas will require the installation of many other measures listed in other subsections of Chapter 7.

It is extremely important to note that these measures require intensive maintenance and require frequent monitoring, cleanout, repair and/or replacement. Where applicable, traffic barricades should also be installed around curb and paved area inlet protection measures to prevent vehicles from hitting the protection devices.

The selection of any type of inlet protection should be based on the principal that the storm drain inlet continue to function and to carry runoff. Blocking the inlet may result in excessive or prolonged ponding/flooding. Blocking flow may also result in bypass of the storm sewer system that may redirect water to an area that results in erosion or damage to private property.

The measures illustrated in this section are a small representation of inlet protection devices that are available for use in curb and paved areas. Field modification by contractors of these measures is not uncommon and have proven to be innovative and effective. In addition, there are many types of curb/paved inlet protection devices available commercially. When selecting or modifying a device it is important that the device used will allow the storm drain to function and carry runoff in the event it plugs or an excessive storm event occurs.

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Stone Bag Curb Inlet Protection

Stone bag curb inlet protection *is a temporary sediment control measure consisting of bags filled with gravel or aggregate and placed around a storm drain curb inlet.*

Purpose

- To minimize sediment from entering storm sewer curb inlets while allowing full use of the storm drainage system during construction activities.
- To trap sediment on paved streets that receive relatively small runoff flows.

Note: **This measure should be used in conjunction with other sediment control measures.**

Specifications

Contributing Drainage Area

One acre maximum.

Capacity

Runoff from a two-year frequency, 24-hour storm event entering a storm drain without bypass flow.

Location

- At curb inlets on paved roads where ponding is likely to occur without bypass flow.
- Down grade from construction activities (e.g., individual home sites).
- Up-slope side of storm drain inlets.
- Around storm drain inlets in sump (depressional) areas.

Barrier

- Height – One to three layers of bags (as necessary).
- Length – Three feet minimum (or as needed to intercept runoff).

Materials

- Bags – UV-stabilized geotextile fabric.
- Traffic Barricades – As needed, to prevent vehicles from hitting the barrier.
- Gravel or INDOT CA No. 5 washed aggregate.

Note: **Gravel or aggregate must be larger than storm sewer grate openings to prevent it from falling into the storm sewer in the event a bag breaks.**

Installation

1. Fill bags approximately one-half full with washed gravel or aggregate.
2. For inlets located on a slope gradient (see Exhibit 1):
   a. At a position(s) up slope of the inlet, lay bags tightly in a row curving up slope from the inlet and away from the curb.
   b. Overlap bags onto the curb and extend a minimum of three feet into the street, keeping bags tightly abutted together.
   c. For additional layers of bags, overlap the bags with the row beneath and leave a one-bag gap (at or below curb height) in the middle of the top row to serve as a spillway. If the spillway height is higher than the top of the curb, place additional bags along the curb to prevent bypass flow.
   d. For additional storage capacity, construct a series of stone bag barriers along the curb so each one traps small amounts of sediment.
3. For inlets located in a depressional (sump) position (see Exhibit 2):
   a. Place bags in an arc around the curb inlet.
   b. Overlap bags onto the curb, keeping bags tightly abutted together.
   c. For additional layers of bags, overlap the bags with the row beneath and leave a one-bag gap (at or below curb height) in the middle of the top row to serve as a spillway. If the spillway height is higher than the top of the curb, place additional bags along the curb to prevent bypass flow.
4. Place a traffic barricade at each installed measure for safety and to protect measure integrity.

Maintenance

- Inspect daily.
- Remove accumulated sediment from paved area (**do not flush with water**) after each storm event. Deposit sediment in an area where it will not re-enter the paved area or storm drains.

- Inspect for damage by vehicular traffic and repair if needed.
- When the contributing drainage areas have been stabilized, remove inlet protection.

Exhibit 1

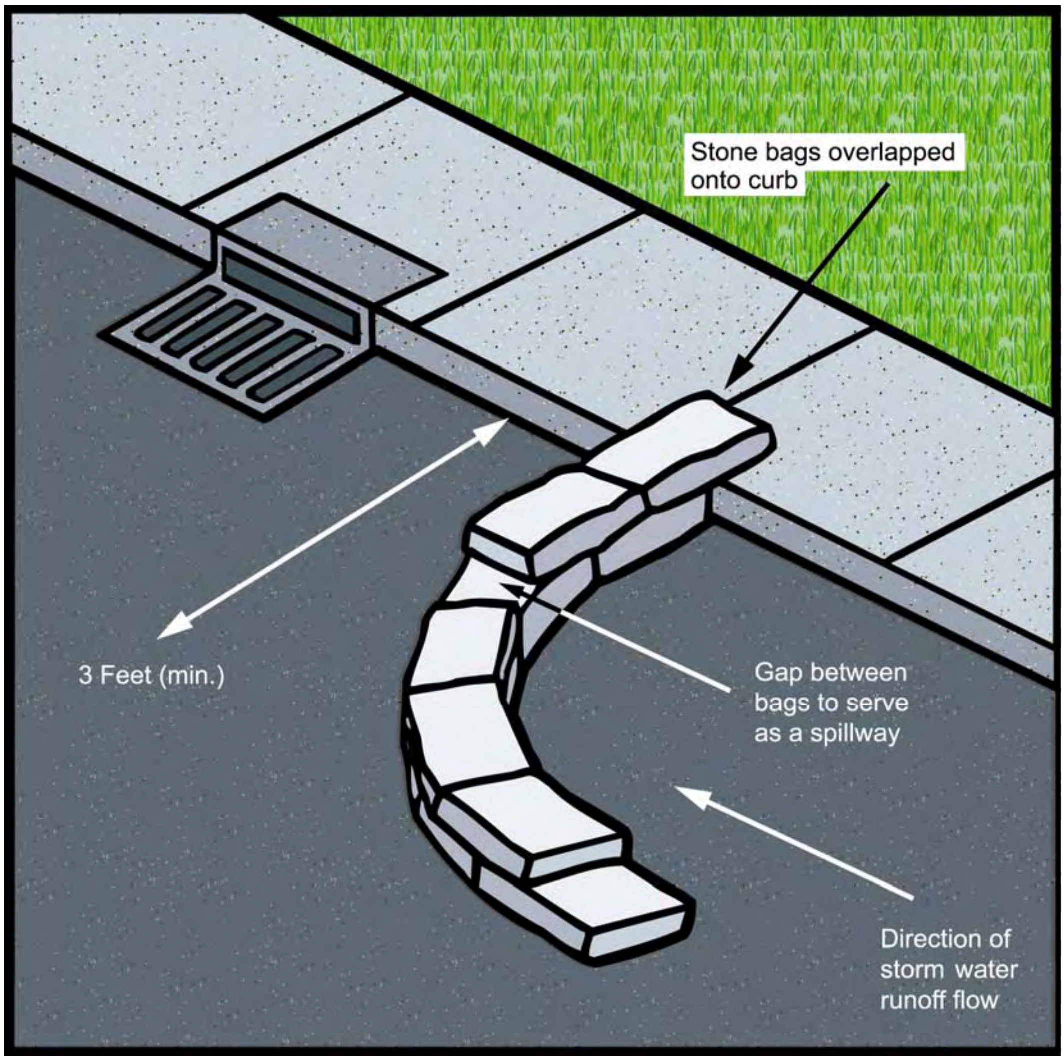
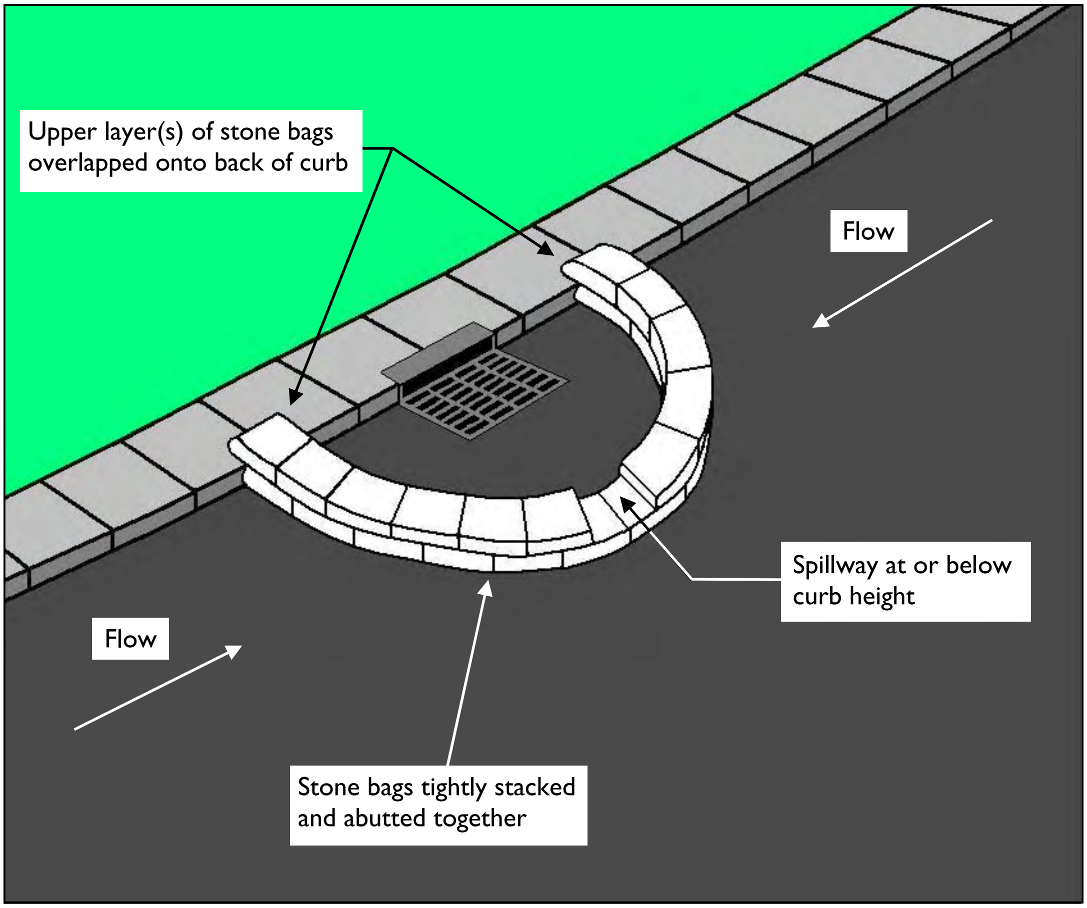
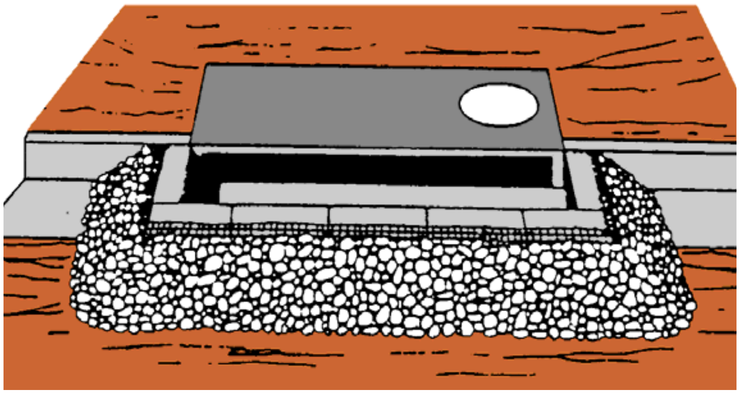


Exhibit 2


Upper layer(s) of stone bags overlapped onto back of curb
Flow
Spillway at or below curb height
Flow
Stone bags tightly stacked and abutted together

Block & Gravel Curb Inlet Protection



Source: Adapted from Virginia Department of Conservation and Recreation, Division of Soil and Water Conservation

***Block and gravel curb inlet protection** is a temporary sediment control measure consisting of concrete blocks and aggregate placed around a storm drain curb inlet.*

Purpose

- To minimize sediment from entering storm sewer curb inlets while allowing full use of the storm drainage system during construction activities.
- To minimize ponding at an inlet.

Note: **Use this measure only where traffic would not be adversely affected.**

Specifications

Contributing Drainage Area

One acre maximum.

Capacity

Runoff from a two-year frequency, 24-hour storm event entering a storm drain without bypass flow.

Location

At curb inlets on paved roads where ponding is likely to occur without bypass flow.

Materials

- Standard eight-inch concrete blocks.
- Hardware cloth with ½-inch openings.
- INDOT CA No. 5 aggregate (see Appendix D).

Note: **INDOT CA No. 8 aggregate is acceptable if No. 5 aggregate is not available. The use of No. 8 aggregate may result in more frequent overtopping of the structure and will increase the frequency of structure maintenance.**

- Traffic Barricades – as needed, to prevent vehicles from hitting the barrier.

Installation

1. At each side of the storm drain inlet, place a concrete block (to serve as a spacer block) lengthwise out from the curb with block openings parallel to the street surface.

2. Place a row of concrete blocks (openings parallel to the street surface) across the front of the inlet and abutting the spacer blocks.

3. Cut a 2 x 4 inch wood stud equal to the length of the inlet plus spacer blocks. Insert the wood stud through the street-side opening of the spacers to keep the row of blocks ahead of it from being pushed back toward the inlet (see Exhibit 2).

4. Run hardware cloth from the top of the blocks, down the outside vertical face and extend to about 12 inches into the street (see Exhibit 2).

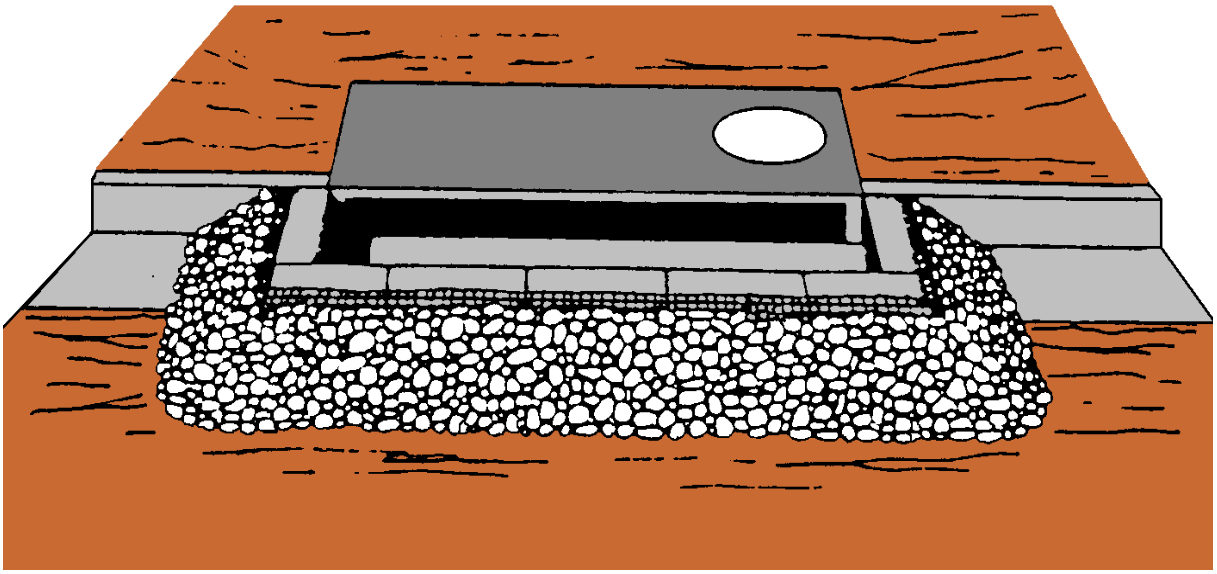
5. Place INDOT CA No. 5 aggregate (for filtration) over the hardware cloth on the outside face of the concrete block barrier, covering it to the top of the blocks. If the top of the curb is rounded over, use extra hardware cloth and aggregate to fill in the space between the spacer blocks and the curb.

6. Place a traffic barricade at each installed measure for safety and to protect measure integrity.

Maintenance

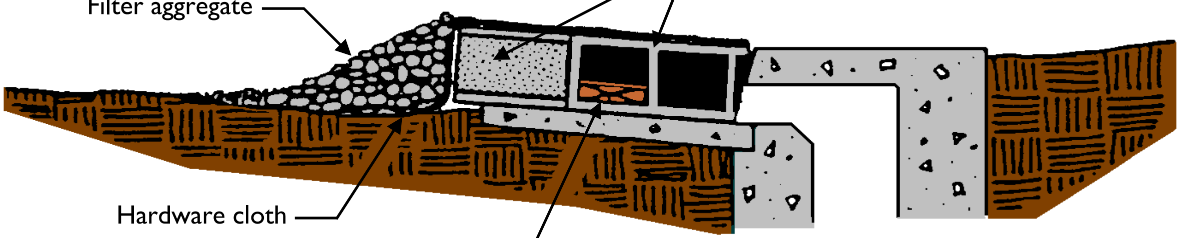
- Inspect daily.
- Remove accumulated sediment and replace aggregate as needed to maintain flow.
- Remove accumulated sediment from paved area (**do not flush with water**) after each storm event.
- Deposit sediment in an area where it will not re-enter the paved area or storm drains. When the contributing drainage area has been stabilized, remove and properly dispose of accumulated sediment, aggregate, hardware cloth, and concrete blocks.

Exhibit 1



Source: Adapted from Virginia Department of Conservation and Recreation, Division of Soil and Water Conservation

Exhibit 2


Blocks laid with openings horizontal to pavement to allow for drainage
Filter aggregate
Hardware cloth
2 inch x 4 inch wood stud

Insert (Basket) Curb Inlet Protection

Insert (basket) curb inlet protection *is a temporary sediment control measure consisting of a metal frame or basket that is used to support a geotextile fabric. The system is installed under the storm sewer grate.*

Purpose

To minimize sediment from entering the storm sewer system while allowing runoff to enter the storm sewer system in the event of excessive storm events. This measure traps sediment associated with small storm events below the grade of the paved area. This measure does not place an obstruction in the street to trap sediment and is especially conducive to stages of construction when the public has access to the project site.

Note: **This measure should be used in conjunction with other sediment control measures.**

Specifications

Contributing Drainage Area:

One-quarter acre maximum.

Capacity

Runoff from a two-year frequency, 24-hour storm event entering a storm drain without bypass flow.

Location

- At curb inlets on paved roads and parking lots.
- Down grade from construction activities (e.g., individual home sites).

Materials

- Metal frame or basket with a top width and length such that the frame fits into the inlet. (The frame is supported by the structural integrity of the storm sewer.)
- The metal frame or geotextile should be designed with a bypass to allow storm water to flow into the storm sewer system during excessive storm events.
- The system should be designed for ease of maintenance.
- Geotextile fabric.

Table 1. Geotextile Fabric Specifications

Physical Property	Woven	Non-Woven
Filtering Efficiency	85%	85%
UV Resistance (Inhibitors and stabilizers to ensure six month minimum life at temperatures of 0° F to 120° F)	70%	85%
Tensile Strength at 20% Elongation:		
Standard Strength	30 lbs./linear inch	50 lbs./linear inch
Extra Strength	50 lbs./linear inch	70 lbs./linear inch
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.

Installation

1. Remove the storm sewer grate and place the frame into the grate opening.
2. Place geotextile fabric into the frame and secure according to the manufacturer's recommendations.
3. Replace the storm sewer grate.

Maintenance

- Inspect daily.
- Remove accumulated sediment and debris after each storm event. Deposit sediment in an area where it will not re-enter the paved area or storm drains.
- Replace or clean geotextile fabric as needed.
- When the contributing drainage area has been stabilized, remove inlet protection.

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SEDIMENT TRAPS & BASINS

Reducing erosion at the source is much more effective and efficient than trying to trap suspended sediment in surface water runoff. Timely installation of temporary and permanent soil stabilization measures, such as those listed in the Surface Stabilization section on pages 29–72, can greatly reduce erosion and sediment loads and reduce frequency of maintenance operations. However, this is not always practical or possible.

When erosion cannot be controlled at the source it becomes necessary to implement sediment control measures designed to collect, control, and treat the resultant sediment-laden surface water runoff. The principal behind all sediment control measures is relatively simple. Slow or pond the sediment-laden surface water runoff for a sufficient length of time to allow the suspended soil particles to settle out.

The measures in this section have been designed specifically to collect and temporarily retain sediment-laden surface water runoff for a specified time to allow suspended soil particles to settle out. These systems do not provide efficiency levels to remove all soil particles that are contained in runoff. The overall effectiveness of these measures can be improved by utilizing additional erosion and sediment control measures within the same drainage area.

These measures are intended for use on large areas and where there are concentrated flows. Often, other measures such as temporary and permanent diversions (designed to collect and channel surface water runoff) must be used in conjunction with these measures.

Designs for sediment traps and basins can be complex and in many cases may require detailed site investigations and the application of sound engineering principles. A professional knowledgeable of the principles of storm water management and experienced in structural design should be consulted when using these measures.

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Temporary Sediment Trap

*A **temporary sediment trap** is a sediment control measure consisting of a small, temporary settling basin formed by construction of an embankment and/or excavated basin with an outlet control structure.*

Purpose

- To minimize sediment release from construction areas by pooling (retaining) storm water runoff and allowing sufficient retention time for settling of suspended soil particles.
- To minimize offsite sedimentation by trapping sediment at designated locations accessible for cleanout.

Specifications

Drainage Area

Five acres maximum (designed by a qualified individual/professional engineer; larger drainage areas may be accommodated but may require additional design considerations).

Structure Life

Typically two years.

Pool Area

- Sediment Storage Volume – minimum of 1,800 cubic feet per acre of watershed's **total** contributing drainage area.
- Surface Area – variable (the larger the surface area, the greater the trapping efficiency).
- Side Slopes – 2:1 ratio or flatter.

- Bring storm drain pipe and channel discharges into the sediment trap at a low velocity.
- Shape – length to width ratio of 2:1 or greater.
- Flow Path Length – locate concentrated storm water inflow(s) as far away from the sediment trap outlet as possible (provides for maximum flow path length, detention time, and pollutant removal).
- Dewatering – pond should completely drain within 48 to 72 hours of a storm water runoff event.

Embankment

- Fill Material
  - Stable mineral soil.
  - Machine compacted in six to eight-inch lifts while the earth fill is still moist.
- Height – five feet maximum.
- Top width – five feet minimum.
- Side slopes – 2:1 ratio or flatter.

Outlet

- Capacity – routed two-year frequency, 24-hour duration storm event.
- Spillway
  - Depth – minimum of 1½ feet below top of settled embankment.
  - Bottom Width – based on drainage area as shown in Table 1.
  - Side Slopes – 2:1 ratio or flatter.
  - Inside face lined with a 12-inch thick layer of INDOT CA No. 5 aggregate.
  - Protection From Piping – Cut-off trench between stone spillway outlet section and compacted embankment with geotextile fabric for separation.

Table 1. Temporary Sediment Trap Spillway Design Specifications

Drainage Area	Minimum Bottom Width
1 acre	4 feet
2 acres	6 feet
3 acres	8 feet
4 acres	10 feet
5 acres	12 feet

- Apron
  - Grade – level, where feasible, with filter fabric foundation to ensure exit velocity is nonerosive.
  - Length – based on outlet size, location, and grade [see **Energy Dissipater (Outlet Protection)** on page 121] but no shorter than five feet.
  - Plunge pool (optional) – used to reduce discharge velocities.

Materials

- INDOT revetment riprap (see Appendix D).
- INDOT CA No. 5 aggregate (see Appendix D).

  Note: **INDOT CA No. 8 aggregate is acceptable if No. 5 aggregate is not available. The use of No. 8 aggregate may result in more frequent overtopping of the structure and will increase the frequency of structure maintenance.**
- Geotextile fabric.
- Cleanout reference stake(s).

Installation

Location and Layout

1. Locate the sediment trap as near to the sediment source as topography allows.
2. Lay out the location and shape of the sediment trap allowing for a length to width ratio of 2:1 or greater.
3. Locate concentrated storm water inflows as far away from the sediment trap outlet as possible.
4. Where applicable, divert runoff from adjoining, undisturbed areas away from the sediment trap and install downstream sediment control measures to prevent off-site damages during construction of the sediment trap.

Embankment

1. Clear, grub, and strip all vegetation and root mat from the embankment area.
2. Construct the embankment in six to eight-inch lifts, compacting each lift as it is placed. Construct the embankment with 2:1 or flatter side slopes. (Material used to construct the embankment must be a stable mineral soil that is free of rocks, brush, roots, and other debris. The soil material must be wet enough to form a ball without crumbling, yet not so wet that water can be squeezed out of it. Place the most permeable soil material in the downstream toe of the embankment and the least permeable material in the center and on the up slope

side of the embankment. To improve stability of the stone spillway, 3:1 side slopes are recommended for the embankment back slope.)

3. Construct the embankment six inches above design elevation to allow for settling.

Outlet

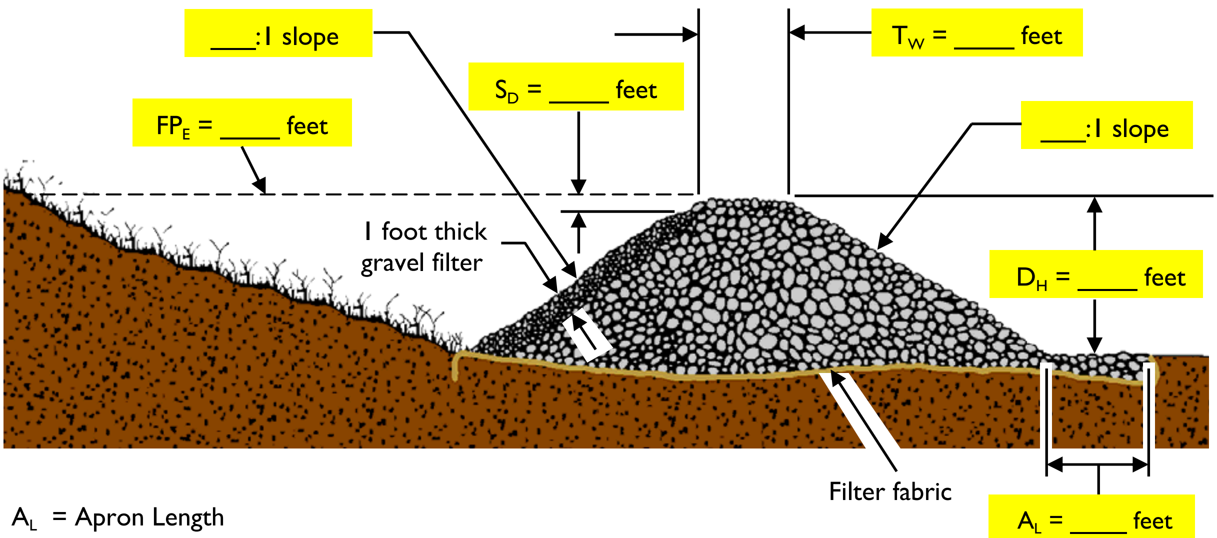
1. Excavate a trapezoidal outlet section in the compacted embankment. Excavate the outlet section to the base of the pool area.
2. Install geotextile fabric in the trapezoidal outlet section, extending the fabric up the sides of the outlet section to the top of the embankment.
3. Place INDOT revetment riprap to the lines and grades shown in the construction plans, working smaller stones into voids to achieve a dense mass. The spillway crest must be level with a minimum depth of 1½ feet, measured from the highest stones in the spillway weir notch to the top of the dam.
4. Cover the upstream face of the riprap outlet section with a 12-inch thick layer of INDOT CA No. 5 aggregate (for filtration).
5. On the downstream side of the spillway, construct an outlet apron at the toe of the embankment. Construct the apron to the lines and grade shown in the construction plans.
   Note: **Outlet apron length must extend to a stable area of the stream channel.**
6. Place geotextile fabric or aggregate bedding material on the compacted and smoothed foundation and install riprap to the lines and elevations shown in the construction plans.
7. Construct a small plunge pool within the outlet apron. (Riprap aprons must be level with or slightly lower than the receiving channel and should not produce an overfall or restrict flow of the water conveyance structure.)
8. Stabilize the embankment and other disturbed areas with seed and mulch (anchored in place) or another suitable erosion resistant cover.
9. Place a sediment cleanout reference stake at the 50 percent design volume elevation of the sediment trap.

Maintenance

- Inspect within 24 hours of a rain event and at least once every seven calendar days.
- Check the embankment for erosion and piping holes; repair immediately.
- Check pool area side slopes for erosion, repair immediately.
- Remove sediment when it has accumulated to one-half the design volume.

- Replace spillway aggregate facing if the sediment pool does not dewater (drain) within 48 to 72 hours following a storm water runoff event.
- Inspect vegetation; reseed if necessary.
- Check spillway depth periodically to ensure a minimum depth of 1½ feet from the lowest point of the settled embankment to the highest point of the spillway crest; fill any low areas to maintain design elevation.
- Promptly replace any displaced riprap, being careful that no stones in spillway are above design grade.
- After all disturbed areas have been stabilized, remove accumulated sediment and the embankment structure, smooth the site to blend with adjoining areas, and stabilize with seed and mulch or another appropriate nonerosive cover.

Temporary Sediment Trap
Rock Dam Worksheet



A_L = Apron Length

D_H = Dam Height

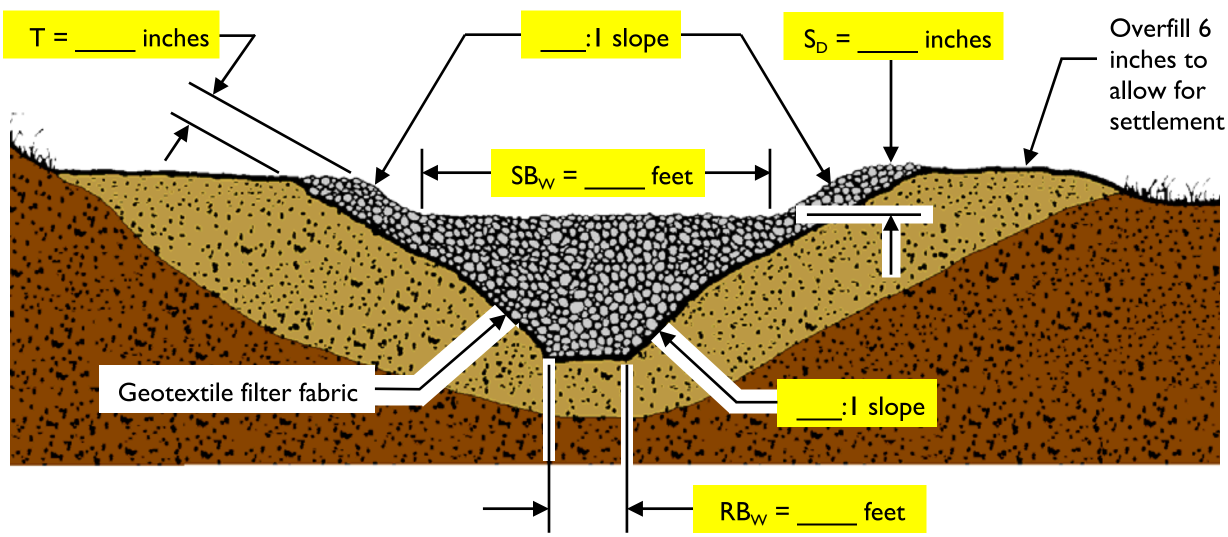
FP_E = Flood Pool Elevation

S_D = Spillway Depth

T_W = Top Width

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

Temporary Sediment Trap
Outlet Worksheet



RB_W = Rock Dam Bottom Width

S_D = Spillway Depth

SB_W = Spillway Bottom Width

T = Spillway Side-Slope Armament Thickness

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

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Temporary Dry Sediment Basin

*A **temporary dry sediment basin** is a sediment control measure consisting of a temporary settling basin formed by construction of an embankment and/or excavated basin. Temporary dry sediment basins are typically designed with a principle spillway, emergency spillway and dewatering structure to control water levels and maximize sediment trapping efficiency.*

Purpose

- To minimize sediment release from construction areas by pooling (retaining) storm water runoff and allowing sufficient retention time for settling of suspended soil particles.
- To minimize off-site sedimentation by trapping sediment at designated locations accessible for cleanout.

Notes:

1. **This measure 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.**
2. **This measure is designed specifically for temporary control of storm water runoff and sediment from large areas where sediment traps or other sediment control measures are not appropriate. Permanent storm water management ponds may be used as temporary sediment basins provided that they meet the requirements of this section and that the construction sequence addresses converting the temporary sediment basin to the permanent storm water management pond.**

Specifications

Contributing Drainage Area

30 acres maximum (designed by a qualified individual/professional engineer; larger drainage areas may be accommodated but may require additional design considerations.)

Structure Life

Typically three years.

Siting

- Avoid steep slopes; slopes should be 2:1 or flatter.
- Locate as close to sediment sources as possible.
- Consider soil type, pool area, embankment length, spillway conditions, accessibility, and ease of cleanout.

Pool Area

- Design volume (storm water storage volume)
  - Provide a minimum storage volume below the crest of the emergency spillway to contain the runoff from a 10-year frequency, 24-hour duration storm event. (Assume zero discharge through the principle spillway and perforated riser when calculating design storage volume.)
  - Measured one foot below the spillway crest.
- Sediment Storage Volume – minimum of 1,800 cubic feet per acre of disturbed drainage area.
- Surface Area – variable (the larger the surface area, the greater the trapping efficiency).
- Side Slopes – 2:1 or flatter.
- Bring storm drain pipe and channel discharges into the sediment basin at a low velocity.
- Flow Path Length
  - Locate concentrated storm water inflow(s) as far away from the sediment basin outlet as possible (provides for maximum flow path length, detention time, and pollutant removal).
  - Flow path length to basin effective width ratio must be 2:1 or greater. [This is calculated by taking the total distance from the concentrated in-

flow point to the outlet riser and dividing it by the basin effective width. This value should be equal to or greater than two. (Note: Basin effective width is calculated by dividing the surface area of the 10-year, 24-hour duration storm event pool elevation by the distance between the inflow point and the outflow point at the outlet control structure in the basin.)]

- Baffle
  - Used to increase flow path length between concentrated storm water inflow(s) into the basin and the basin outflow (outlet).
  - May consist of baffle boards or an earthen embankment.
- Dewatering – pond should completely drain within 48 to 72 hours of a storm water runoff event.
- Accessibility – provide accessibility for mechanical cleanout and maintenance of the pool area.

Dam/Embankment

- Height – 10 feet maximum or as per design.
- Top Width – six feet minimum.
- Side Slopes – 2.5:1 or flatter.
- Settlement Allowance – 10 percent of design height.
- Fill Material – stable mineral soil compacted in six to eight-inch lifts while the earth fill is still moist.
- Cut-off Trench
  - Depth – two feet minimum.
  - Width – two feet minimum.
  - Side slopes – 1:1.
  - Along the center line of the embankment.
  - Backfilled with highly impermeable soil material.

Outlet

- Principal spillway
  - Capacity – runoff from a 10-year frequency, 24-hour duration storm event without discharging through the emergency spillway.

- Barrel
  - Must be able to withstand maximum external loading without yielding, buckling or cracking.
  - Anti-seep collar – watertight collar, with a 1½ foot minimum projection, placed around the barrel of the outlet pipe (used on pipes with an eight-inch diameter or larger).
- Riser
  - Must be able to withstand maximum external loading without yielding, buckling or cracking.
  - Height – at a minimum, the crest elevation of the riser pipe must be set at the five-year frequency, 24-hour duration storm event pool elevation and at least one foot below the elevation of the crest or control section of the emergency spillway.
  - Perforated (one-half inch holes spaced three inches apart or use a premanufactured perforated riser pipe) for dewatering and wrapped with hardware cloth or suitable wire mesh to a height above the perforations to prevent stones from the aggregate filter pack from plugging the perforations.
  - Wrapped with an aggregate filter pack consisting of INDOT Uniform A or B riprap or INDOT CA No. 2 aggregate covered with a minimum of 12 inches of INDOT CA No. 5 aggregate for filtration. (INDOT CA No. 8 aggregate is acceptable if No. 5 aggregate is not available. The use of No. 8 aggregate may result in more frequent overtopping of the structure and will increase the frequency of structure maintenance.)
  - Aggregate filter pack must be a minimum of 12 inches thick over all riser perforations.
  - Trash guard and anti-vortex baffle at top of riser pipe.
- Apron
  - Riprap outlet apron needed unless foundation is rock.
  - Stable and sized for design of pipe discharge.
  - Length – based on outlet size, location, and grade but no shorter than five feet.
  - Grade – level, where feasible, with filter fabric foundation to ensure exit velocity is nonerosive.
  - Filter fabric placed over apron foundation.
  - Plunge pool (optional) – used to reduce discharge velocities.
- Anti-flotation block – 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.

• Emergency Spillway

- Capacity – routed peak flow from a 25-year frequency, 24-hour duration storm event **plus** one foot of freeboard.

- Location – constructed in undisturbed soil.
- Cross Section – trapezoidal with side slopes 3:1 or flatter.
- Control Section – level, straight, at least 20 feet long.
- Approach Channel
  - Two percent slope, minimum.
  - Width – 1½ times the width of the emergency spillway base through the control section.
- Stabilized with erosion control blankets, riprap, or another suitable non-erosive material.
- Apron
  - Riprap outlet apron needed unless foundation is rock.

Materials

- Riser and barrel pipes.
- Anti-seep collar.
- Anti-flotation block.
- Trash guard.
- Geotextile fabric.
- Hardware cloth or wire mesh.
- INDOT Uniform A or B riprap or INDOT CA No. 2 aggregate.
- INDOT CA No. 5 aggregate.
- Clean-out reference stake(s).
- Erosion control blankets or a nonerosive material (for stabilization of the emergency spillway).

Installation

Location and Layout

1. Locate the sediment basin as near to the sediment source as topography allows, taking into consideration the soil type, pool area, length of the dam, outlet location, spillway conditions, and accessibility for cleanout and maintenance of the basin/pool area.
2. Lay out the location and shape of the sediment basin, allowing for a length to width ratio of 2:1 or greater.
3. Locate concentrated storm water inflow(s) as far away from the basin outlet as possible. If the storm water inflow(s) cannot be located at or near the up-slope end of the basin, install a baffle(s) to achieve a minimum flow path length of 2:1 or greater.
4. Where applicable, divert runoff from adjoining, undisturbed areas away from the sediment basin and install downstream sediment control measures to prevent off-site damages during construction of the sediment basin.

Apron and Sub-Base Preparation

1. Clear, grub, and strip all vegetation and root mat from the area where the dam is to be located and from the pool area, properly disposing of all trees, logs, limbs, vegetative matter, rocks and other objectionable materials in pre-designated disposal areas.
2. Excavate the area for the outlet apron and embankment, stockpiling any surface soil material containing a high amount of organic matter.
3. Excavate a two-foot wide by two-foot deep, minimum, cut-off trench with 1:1 side slopes along the center line of the embankment, extending it all the way up the embankment side slopes.
4. Place highly impermeable soil material in the cut-off trench. Place material in six to eight-inch lifts, compacting each lift as it is placed.
5. Excavate the outlet apron, allowing for the thickness of the filter medium and riprap.
6. Line the apron excavation with the specified filter medium and place INDOT Uniform A or B riprap with a d_{50} of nine inches, or greater, to the lines and grade shown in the construction plans.

Principal Spillway

1. Install the spillway barrel (pipe) and riser on a firm, even foundation. Place at least one watertight anti-seep collar (1½ foot minimum projection) around the barrel if it is eight inches or larger in diameter.
2. Place a four-inch layer of moist, clayey, soil around the lower part of the barrel and compact it by hand to at least the density of the soil foundation, taking care **not to** raise the barrel from the foundation when compacting under the barrel haunches. (Do not use soil materials such as sand, aggregate or silt.)
3. Perforate the riser pipe with one-half inch holes spaced three inches apart or use a manufactured perforated riser pipe.
4. Connect the riser pipe to the barrel.
5. Embed the riser pipe in at least 12 inches of concrete (the concrete serves as an anti-flotation block).
6. Wrap the perforated riser with hardware cloth or wire mesh.
7. Place an aggregate filter pack around the perforated riser. [The filter pack should consist of 12 inches of INDOT Uniform A or B riprap or INDOT CA No. 2 aggregate placed around the riser and then covered with a minimum of 12 inches of INDOT CA No. 5 aggregate (for filtration)].
8. Install a trash guard (bars two to three inches apart) on the top of the riser pipe.

Embankment and Pool Area

1. Scarify the soil surface in the area of the embankment base location.
2. Using clean, stable mineral soil free of roots, woody vegetation, rocks and other debris, construct the embankment in continuous six to eight-inch lifts over the entire length of the embankment, compacting each lift as it is placed. (Material used to construct the embankment must be a stable mineral soil that is free of rocks, brush, roots, and other debris. The soil material must be wet enough to form a ball without crumbling, yet not so wet that water can be squeezed out of it. Place the most permeable soil material in the downstream toe of the embankment and the least permeable material in the center and on the upslope side of the embankment. Route construction equipment over the length of the dam so that all parts of each soil lift are traversed by at least one wheel of the equipment.
   Note: Protect the spillway barrel with two feet of hand-compacted fill before crossing it with equipment.)
3. Construct and compact the embankment until it is 10 percent above design elevation to allow for settling.
4. Stabilize the embankment with seed and mulch (anchored in place) or another suitable erosion resistant cover.
5. Place a sediment cleanout reference stake at the 50 percent design volume elevation of the sediment basin.

Emergency Spillway

1. Site the emergency spillway at one end of the embankment. Locate it in undisturbed soil outside the construction limits of the embankment.
2. Locate the emergency spillway so that any flow will return to the receiving channel without damaging the embankment.
3. Excavate a trapezoidal channel with 3:1 or flatter side slopes as specified in the construction plans. Maintain a straight, level, 20-foot long, minimum, channel through the control section.
4. Permanent seed (see **Permanent Seeding** on page 35) and protect with erosion control blankets (see **Erosion Control Blanket** on page 63) as soon as grading is complete or, if vegetation is not used or suitable for the soil conditions and slope, install a nonerosive liner to finished grade.

Safety

1. Do not locate in areas where slopes are greater than 2:1.
2. Install a fence around the area and erect warning signs if trespassing is likely.
3. Dewater the basin between storm events.
4. Follow all state and local requirements for impoundment sites.

Maintenance

- Inspect within 24 hours of a rain event and at least once every seven calendar days.
- Remove and properly dispose of sediment when it accumulates to one-half the design volume.
- Periodically check embankment, emergency spillway, and outlet for erosion damage, piping, settling, seepage, or slumping along the toe or around the barrel; repair immediately.
- Remove trash and other debris from riser, emergency spillway, and pool area.
- Clean or replace aggregate around the riser if the sediment pool does not dewater (drain) within 48 to 72 hours following a storm water runoff event.
- Remove basin after drainage area has been permanently stabilized, inspected, and approved. Do so by draining any water, removing sediment to a designated disposal area, smoothing the site to blend with the surrounding area, and then stabilizing with seed and mulch or another appropriate nonerosive cover.

Design Data Sheet

Computed by:_____________________________ Date:______________

Project Name:_____________________________Basin #:_____________

Location: ____

Total watershed area draining to basin: _______________ acres

Total disturbed area draining to basin: _______________ acres

Basin Volume Design

Design volume (minimum required volume for 10-yr. freq. storm event):________ cubic feet

Sediment storage volume (minimum required volume):________ cubic feet

Volume of basin below emergency spillway crest:________ cubic feet

Volume of basin at riser crest elevation (5-year frequency storm event):________ cubic feet

Design Elevations

Emergency Spillway Crest: __________________ feet

Riser Crest: __________________ feet

Top of Dam (settled): __________________ feet

Bottom of Basin: __________________ feet

Flow Path

Surface area of pool at riser crest elevation: _______________ square feet

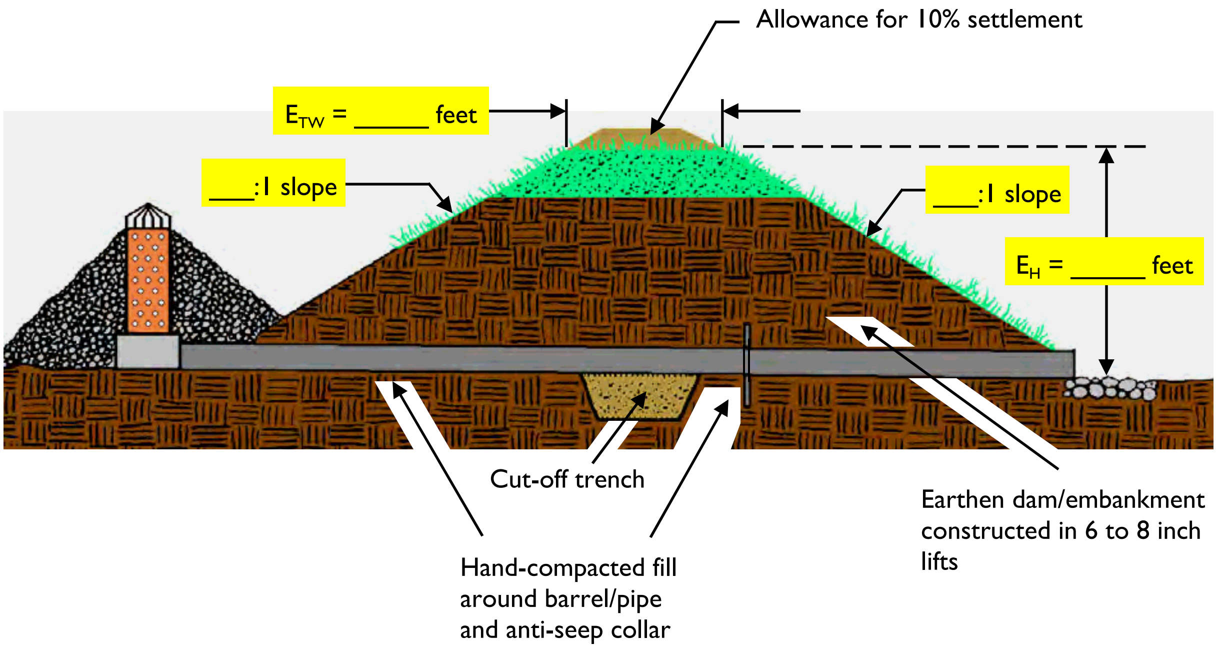
Number of concentrated flows into basin: _______________

Note: The flow path length to basin effective width ratio must be 2:1 or greater. [This is calculated by taking the total distance from the concentrated inflow point to the outlet riser and dividing it by the basin effective width. This value should be equal to or greater than two. (Note: Basin effective width is calculated by dividing the area of the 10-year frequency, 24-hour duration storm event pool elevation by the distance between the inflow point and the outflow point at the outlet control structure in the basin.)]

Do all flow path lengths from concentrated inflows to the riser achieve the 2:1 minimum ratio? Yes: _______ No: _______

If NO, provide details for required baffle(s) to achieve the minimum 2:1 ratio for each concentrated inflow.

Temporary Dry Sediment Basin Earthen Dam/Embankment Worksheet



E_H = Earthen Dam/Embankment Height

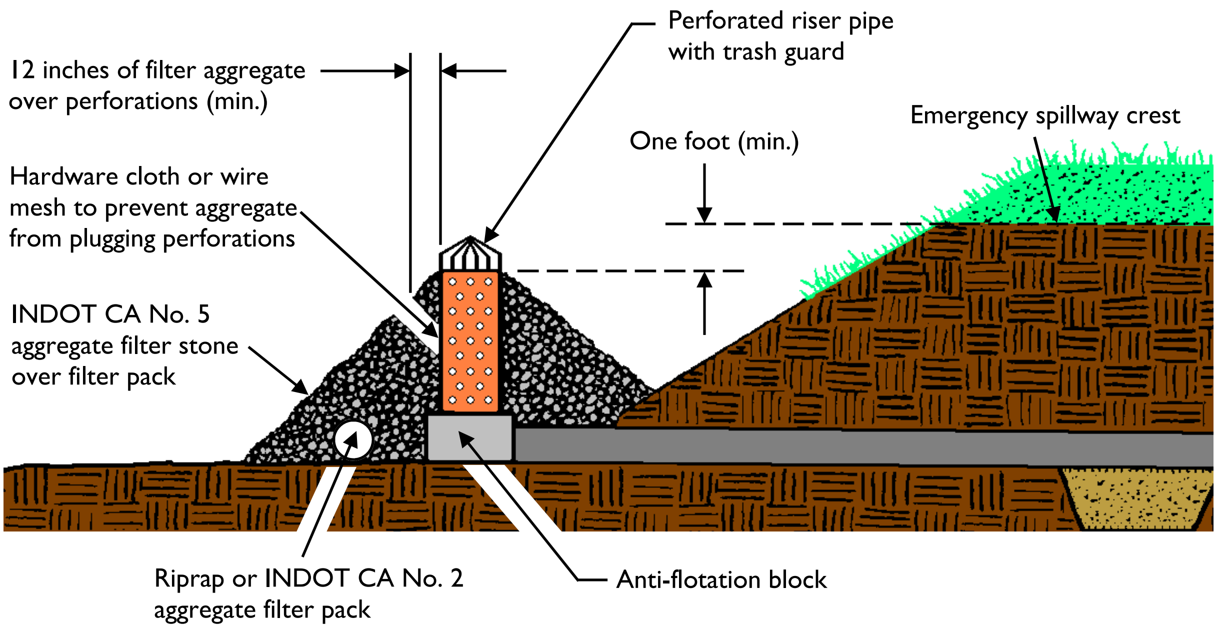
E_{TW} = Earthen Dam/Embankment Top Width

NOTE: For minimum dimensions see the "Specifications" section of this measure.

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

Exhibit 1

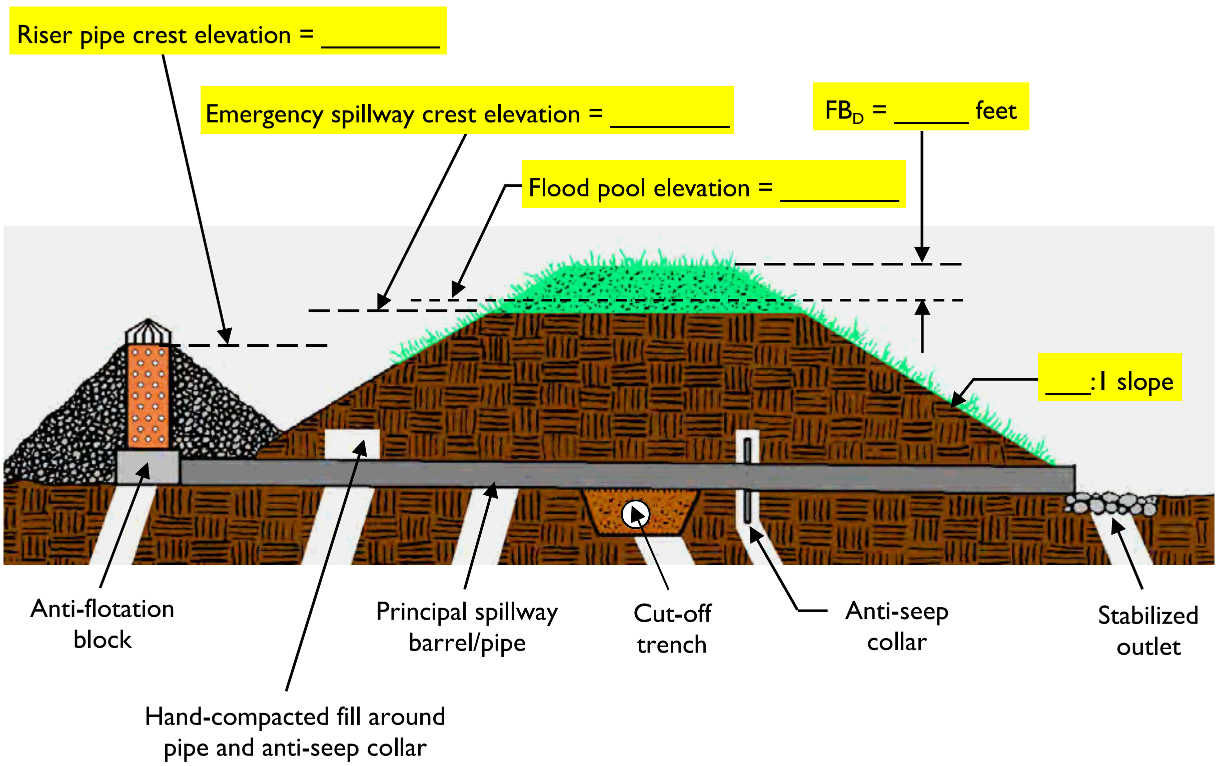
Temporary Dry Sediment Basin
Riser Pipe



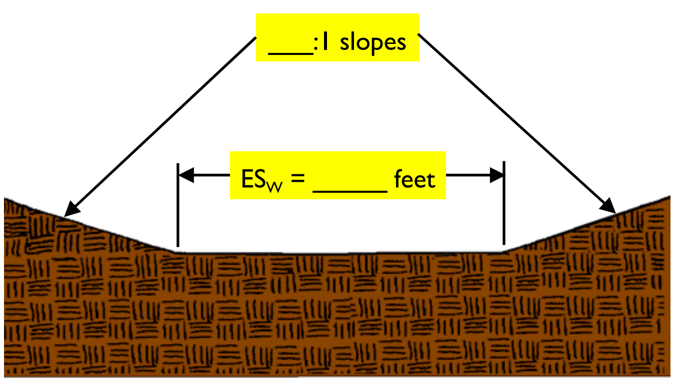
NOTE: For minimum dimensions see the "Specifications" section of this measure.

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

Temporary Dry Sediment Basin
Spillway Worksheet 1



Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993



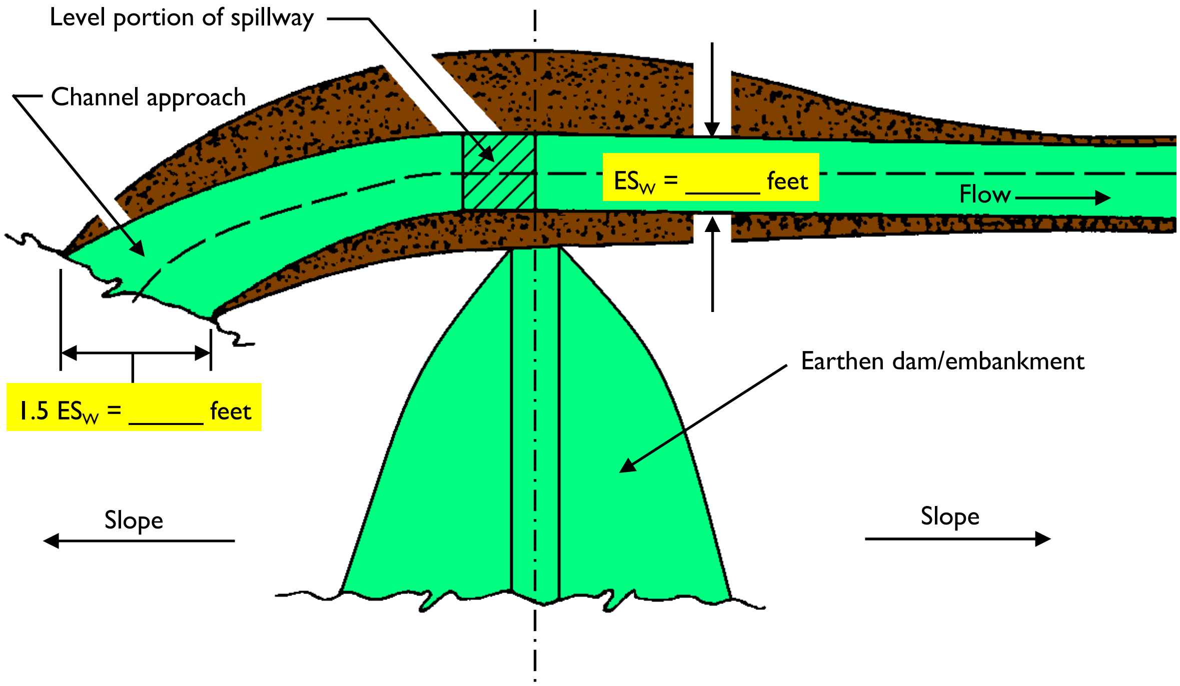
ES$_W$ = Emergency Spillway Width

FB$_D$ = Free Board Depth

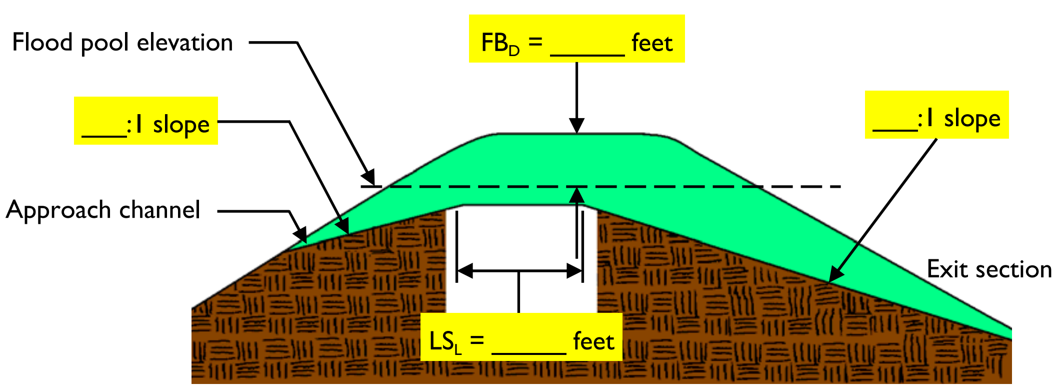
NOTE: For minimum dimensions see the "Specifications" section of this measure.

Source: Adapted from U.S. Department of Agriculture, Natural Resources Conservation Service

Temporary Dry Sediment Basin
Spillway Worksheet 2



Source: Adapted from USDA, Natural Resources Conservation Service



ES_W = Emergency Spillway Width
FB_D = Free Board Depth
LS_L = Level Section Length

NOTE: For minimum dimensions see the "Specifications" section of this measure.

Source: Adapted from USDA, Natural Resources Conservation Service

Retrofitting Storm Water Retention/Detention Basins

To be released at a later time

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Portable Sediment Trap

To be released at a later time

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As has been stated several times in this manual, reducing erosion at the source is much more effective and efficient than trying to trap suspended sediment in surface water runoff. Timely installation of temporary and permanent soil stabilization measures, such as those listed in the Surface Stabilization section on pages 29–72, can greatly reduce erosion and sediment loads and reduce frequency of maintenance operations. Unfortunately, this is not always practical or possible.

When erosion cannot be controlled at the source it becomes necessary to implement sediment control measures designed to collect, control, and treat the resultant sediment-laden surface water runoff. The principal behind all sediment control measures is relatively simple. Slow or pond the sediment-laden surface water runoff for a sufficient length of time to allow the suspended soil particles to settle out.

The measures in this section have been designed specifically to either filter or pond sediment-laden surface water runoff for a limited time to allow suspended soil particles to settle out. The sediment removal efficiency of each measure will vary. The overall effectiveness of these measures can be improved by utilizing additional erosion and sediment control measures within the same drainage area. These measures are intended for use on relatively small, flat areas. They are not designed to withstand high or concentrated flows and excessive sediment loads.

It is important to note that these measures require intensive maintenance and require frequent monitoring, cleanout, repair and/or replacement, especially when sediment loads are high.

The measures illustrated in this section are a representation of sediment barriers and filters. While the measures in this section are representative, there are many variations of these measures that are available commercially. Prior to selecting a measure, it is important that each is evaluated and chosen based on field conditions.

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Vegetative Filter Strip

*A **vegetative filter strip** is a sediment control measure consisting of an existing or newly planted and established vegetative strip located between a construction zone and down-slope site or water-course. This measure is used to filter sediment and other pollutants from storm water runoff discharges.*

Purpose

- To trap sediment from small, disturbed areas by reducing velocity of sheet flow. Vegetative filter strips capture sediment by filtering storm water runoff and allowing sediment to settle out.
- To reduce damage associated with sedimentation.
- To improve water quality.

Note: **Filter strip effectiveness is increased when used in conjunction with other measures, such as sediment barriers, inlet protection, and sediment traps and basins.**

Specifications

Capacity

Depth of concentrated storm water sheet flow no greater than 2½ inches.

Filter Strip Type

- Existing Filter Strip
  - Used where sufficient vegetative cover is already present.
  - Established by stopping earth-disturbing activities at the up-slope edge of the intended filter strip, leaving existing vegetation in the filter strip area intact.

- New Filter Strip
  - Used where site has little or no vegetative cover and lead time is sufficient (e.g., minimum of six weeks during the growing season) to establish four to six-inch high vegetation that covers 80 percent or more of the soil surface.
  - Seeded and established before the up-slope area is disturbed.
- Permanent Filter Strip
  - Used in areas where the filter strip will not be disturbed for at least one year.
- Temporary Filter Strip
  - Used in areas where the filter strip will be disturbed within less than one year or alternative vegetation is desired at a later date.

Filter Strip

- Location – down slope of sediment producing site.
- Width – based on slope of the contributing watershed (see Table 1).

Table 1. Filter Strip Width

Percent Slope Above Filter Strip		Maximum Slope Length Above Filter Strip	Minimum Width
< 5%	< 20:1	100 feet	20 feet
5% to 10%	20:1 to 10:1	75 feet	40 feet
10% to 20%	10:1 to 5:1	50 feet	60 feet
> 20%	> 5:1	Not Recommended	Not Recommended

- Height of Vegetation – maintain a height of four to six inches.
- Grade – one percent or greater, but less than six percent.
- Cover Density – vegetative cover of 80 percent or greater over the soil surface.

Materials

- Seed – Select species or mixture appropriate for soil and site conditions (see Tables 2 and 3).

Table 2. Seed Species and Seeding Rates for Permanent Filter Strips[1]

Seed Species[2]	Rate per Acre
Moderately well and well drained soils	
1. Creeping red fescue (prefers shade) – annual ryegrass	20 lbs. 5 lbs.
2. Tall fescue[3] – annual ryegrass	50 lbs. 5 lbs.
Somewhat poorly, poorly and very poorly drained soils	
1. Tall fescue[3] – annual ryegrass	50 lbs. 5 lbs.

[1] Applies to filter strips that will be in place for one year or more.

[2] Species referenced in Table 3 is also suitable for establishment of filter strips.

[3] Tall fescue provides little cover for and may be toxic to some species of wildlife. The Indiana Department of Natural Resources recognizes the need for additional research on alternatives, such as buffalograss, orchard grass, smooth bromegrass, and switchgrass. This research, in conjunction with demonstration areas, should focus on erosion control characteristics, wildlife toxicity, turf durability, and drought resistance.

Table 3. Seed Species and Seeding Rates for Temporary Filter Strips[1]

Seed Species	Rate per Acre
Annual ryegrass	40 lbs.
Wheat or cereal rye	150 lbs.

[1] Applies to filter strips that will be in place for up to one year.

Installation

Determine the width of the filter strip, based on the slope of the contributing watershed (see Table 1).

Existing Filter Strip

1. Evaluate existing vegetation and determine if it is sufficient for a filter strip [i.e., Does the vegetative cover consist of grasses (weeds are not an acceptable vegetative filter) that are four to six inches high or higher and does it cover 80 percent or more of the soil surface?].

2. If existing vegetation is not adequate, and site conditions and seeding conditions are favorable, overseed the area using a no-till grain drill or

fertilize the existing vegetation to enhance growth and density. Allow time for sufficient vegetative growth before discharging sediment-laden storm water runoff into the filter strip.

New Filter Strip

1. If existing vegetation is not adequate, and site conditions and lead time is sufficient (i.e., minimum of six weeks during the growing season) to establish four- to six-inch high vegetation that covers 80 percent or more of the soil surface, consider establishing a new filter strip.
2. To establish a new vegetative filter strip, temporarily divert storm water runoff away from the site wherever possible (see **Temporary Diversion** on page 75).
3. Prepare the seedbed and add soil amendments (see **Permanent Seeding** on page 35 and **Dormant Seeding and Frost Seeding** on page 41).
4. Plant vegetative species appropriate to the soil and site conditions as shown in Table 2 (Seed Species and Seeding Rates for Permanent Filter Strips) or Table 3 (Seed Species and Seeding Rates for Temporary Filter Strips).
5. Apply mulch (see **Mulching** on page 55 or **Compost Mulching** on page 59) or install erosion control blankets (see **Erosion Control Blanket** on page 63) to newly seeded areas.

Maintenance

- Inspect within 24 hours of a rain event and at least once every seven calendar days.
- Promptly repair any small rills that form.
- Add fertilizer and lime as needed to maintain healthy vegetation.
- Mow as needed but not shorter than four inches.
- Where the filter strip has actively trapped sediment during construction, remove the accumulated sediment, regrade the area and reseed it when conditions are favorable for vegetative establishment.

Silt Fence

*A **silt fence** is a temporary barrier of entrenched geotextile fabric stretched across and attached to supporting posts and installed on the contour to intercept and treat sediment-laden storm water runoff from small, unvegetated drainage areas.*

Purpose

To trap sediment from small, disturbed areas by reducing the velocity of sheet flow. Silt fences capture sediment by ponding water to allow deposition, not by filtration.

Note: **Silt fence is not recommended for use as a diversion and should not be used across a stream, channel, ditch, swale, or anywhere that concentrated flow is anticipated.**

Specifications

Drainage Area

- Limited to one-quarter acre per 100 linear feet of fence.
- Further restricted by slope steepness (see Table 1).

Effective Life

Six months (maximum).

Location

- Installed parallel to the slope contour.
- Minimum of 10 feet beyond the toe of the slope to provide a broad, shallow sediment pool.
- Accessible for maintenance (removal of sediment and silt fence repair).

Spacing

Table 1. Slope Steepness Restrictions

Percent Slope		Maximum Distance
< 2%	< 50:1	100 feet
2% – 5%	50:1 to 20:1	75 feet
5% – 10%[1]	20:1 to 10:1	50 feet
10% – 20%[1]	10:1 to 5:1	25 feet
> 20%[1]	> 5:1	15 feet

[1] Consider other alternatives.

Note: Multiple rows of silt fence are not recommended on the same slope.

Trench

- Depth – eight inches minimum.
- Width – four inches minimum.
- After installing fence, backfill with soil material and compact (to bury and anchor the lower portion of the fence fabric).

Note: **An alternative to trenching is to use mechanical equipment to plow in the silt fence.**

Materials and Silt Fence Specifications

- Fabric – woven or non-woven geotextile fabric meeting specified minimums outlined in Table 2.

Table 2. Geotextile Fabric Specifications for Silt Fence (minimum)

Physical Property	Woven Geotextile Fabric	Non-Woven Geotextile Fabric
Filtering efficiency	85%	85%
Textile strength at 20% elongation Standard strength Extra strength	 30 lbs. per linear inch 50 lbs. per linear inch	 50 lbs. per linear inch 70 lbs. per linear inch
Slurry flow rate	0.3 gal./min./square feet	4.5 gal./min./square feet
Water flow rate	15 gal./min./square feet	220 gal./min./square feet
UV resistance	70%	85%
Post spacing	7 feet	5 feet

Note: Silt fences can be purchased commercially.

- Height – a minimum of 18 inches above ground level (30 inches maximum).
- Reinforcement – fabric securely fastened to posts with wood lathe.
- Support Posts
  - 2 x 2 inch hardwood posts. Steel fence posts may be substituted for hardwood posts (steel posts should have projections for fastening fabric).
  - Spacing
    - Eight feet maximum if fence is supported by wire mesh fencing.
    - Six feet maximum for extra-strength fabric without wire backing.

Installation

Prefabricated silt fence (see Exhibits 1, 2, and 3)

1. Lay out the location of the fence so that it is parallel to the contour of the slope and at least 10 feet beyond the toe of the slope to provide a sediment storage area. Turn the ends of the fence up slope such that the point of contact between the ground and the bottom of the fence end terminates at a higher elevation than the top of the fence at its lowest point (see Exhibit 1).
2. Excavate an eight-inch deep by four-inch wide trench along the entire length of the fence line (see Exhibit 2). Installation by plowing is also acceptable.
3. Install the silt fence with the filter fabric located on the up-slope side of the excavated trench and the support posts on the down-slope side of the trench.

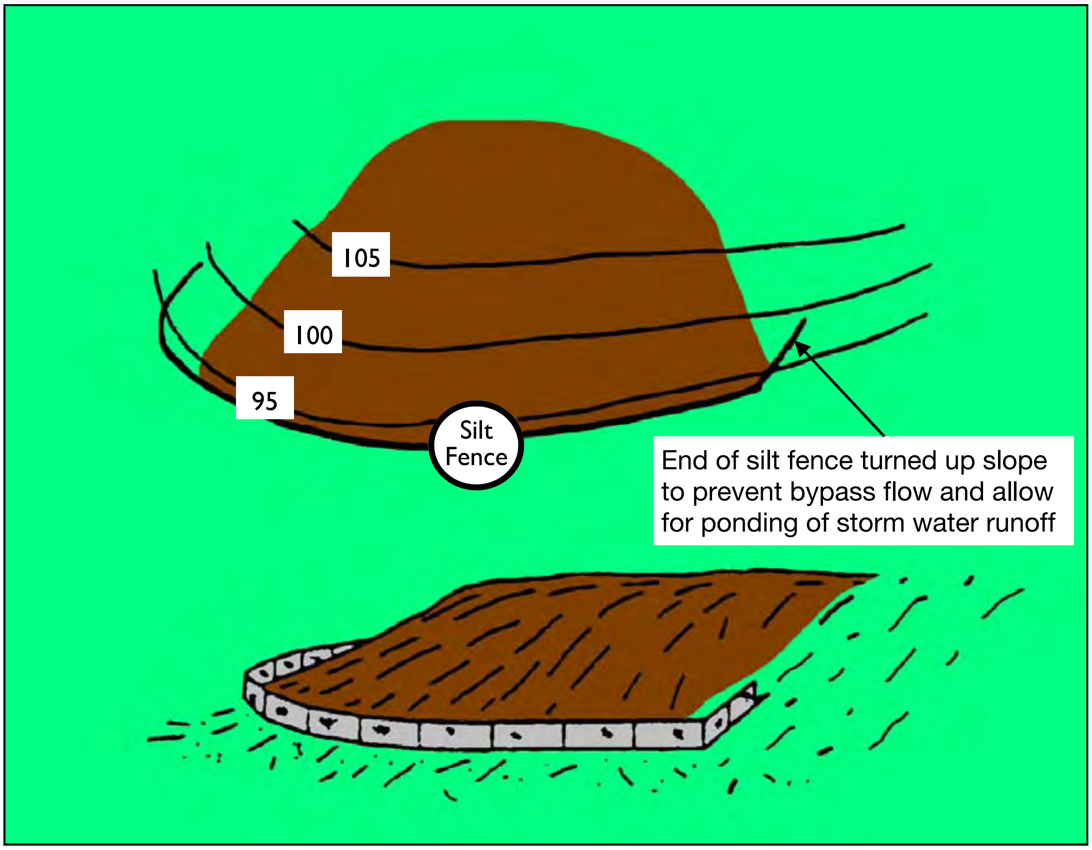
4. Drive the support posts at least 18 inches into the ground, tightly stretching the fabric between the posts as each is driven into the soil. A minimum of 12 inches of the filter fabric should extend into the trench. (If it is necessary to join the ends of two fences, use the wrap joint method shown in Exhibit 3.)
5. Lay the lower four inches of filter fabric on the bottom of the trench and extend it toward the up-slope side of the trench.
6. Backfill the trench with soil material and compact it in place.

Note: **If the silt fence is being constructed on-site, attach the filter fabric to the support posts (refer to Tables 1 and 2 for spacing and geotextile specifications) and attach wooden lathe to secure the fabric to the posts. Allow for at least 12 inches of fabric below ground level. Complete the silt fence installation, following steps 1 through 6 above.**

Maintenance

- Inspect within 24 hours of a rain event and at least once every seven calendar days.
- If fence fabric tears, starts to decompose, or in any way becomes ineffective, replace the affected portion immediately. Note: **All repairs should meet specifications as outlined within this measure.**
- Remove deposited sediment when it is causing the filter fabric to bulge or when it reaches one-half the height of the fence at its lowest point. When contributing drainage area has been stabilized, remove the fence and sediment deposits, grade the site to blend with the surrounding area, and stabilize.

Exhibit 1



Source: Adapted from Commonwealth of Pennsylvania Erosion and Sediment Pollution Control Manual, 1990

Exhibit 2

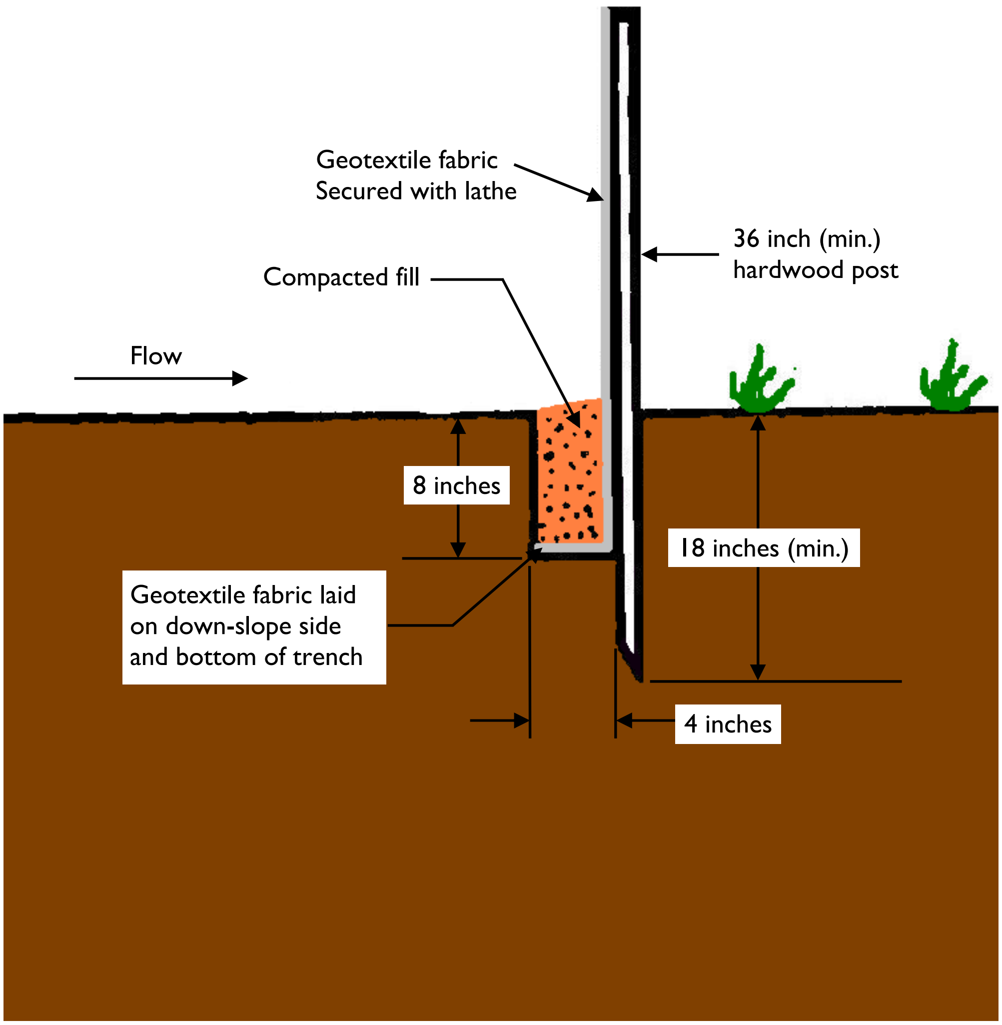
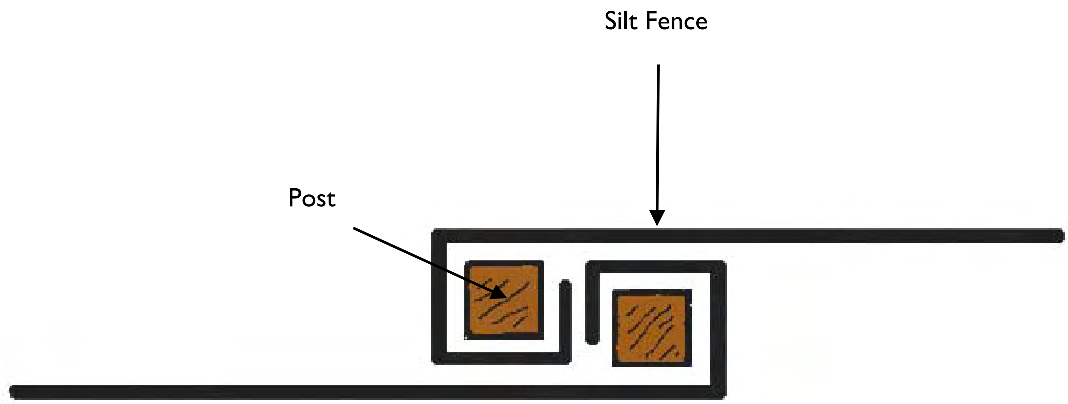

Geotextile fabric
Secured with lathe
Compacted fill
36 inch (min.)
hardwood post
Flow
8 inches
18 inches (min.)
Geotextile fabric laid
on down-slope side
and bottom of trench
4 inches

Exhibit 3



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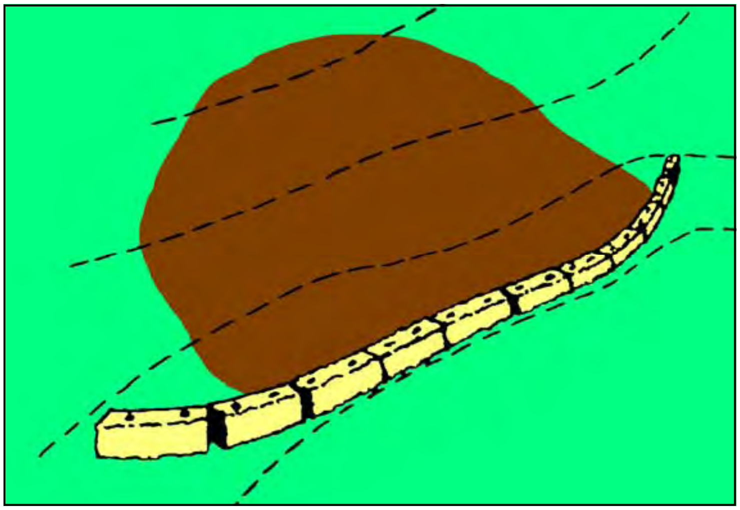
Straw Bale Dam



Source: Adapted from Minnesota Pollution Control Agency, Minnesota Construction Site Erosion and Sediment Control Planning Handbook, 1987

*A **straw bale dam** is a temporary barrier consisting of a row of entrenched and anchored straw bales, or similar material, installed on the contour to intercept and treat sediment-laden storm water runoff from small, unvegetated drainage areas.*

Purpose

To trap sediment from small, disturbed areas by reducing the velocity of sheet flow. Straw bale dams capture sediment by ponding water to allow deposition, not by filtration.

Note: **Straw bale dams should not be utilized as a first choice when selecting a sediment barrier or filter measure. This option should only be used when other materials are not available. Straw bales are <u>not</u> recommended for use as a diversion and should not be used across a stream, channel, ditch, swale, or anywhere that concentrated flow is anticipated; or on paved surfaces, because of the lack of an anchoring system. Straw bales are often specified when clear zone issues are associated with a highway project. This application will require intensive maintenance.**

Specifications

Drainage Area

- Limited to one-quarter acre per 100 linear feet of barrier.
- Further restricted by slope steepness (see Table 1).

Effective Life

Less than three months.

Location

- Installed parallel to the slope contour.
- Minimum of 10 feet beyond the toe of the slope to provide a broad, shallow sediment pool.
- Accessible for maintenance (removal of sediment and straw bale replacement).

Spacing

Table 1. Slope Steepness Restrictions

Percent Slope		Maximum Distance Above Straw Bale Barrier
< 2%	< 50:1	100 feet
2% – 5%	50:1 to 20:1	75 feet
5% – 10%[1]	20:1 to 10:1	50 feet
10% – 20%[1]	10:1 to 5:1	25 feet
> 20%[1]	> 5:1	15 feet

[1] Consider other alternatives.

Note: Multiple rows of straw bale barriers are not recommended on the same slope.

Trench

- Depth – four inches minimum.
- Width – width of straw bale.
- After installing straw bale barrier, backfill with soil material and compact.

Materials

- Straw bales – 14 inches by 18 inches by 36 inches minimum.
- Anchor stakes
  - Steel rebar or 2 x 2 inch hardwood stakes with one end sharpened/pointed.
  - Length – 36 inches minimum.

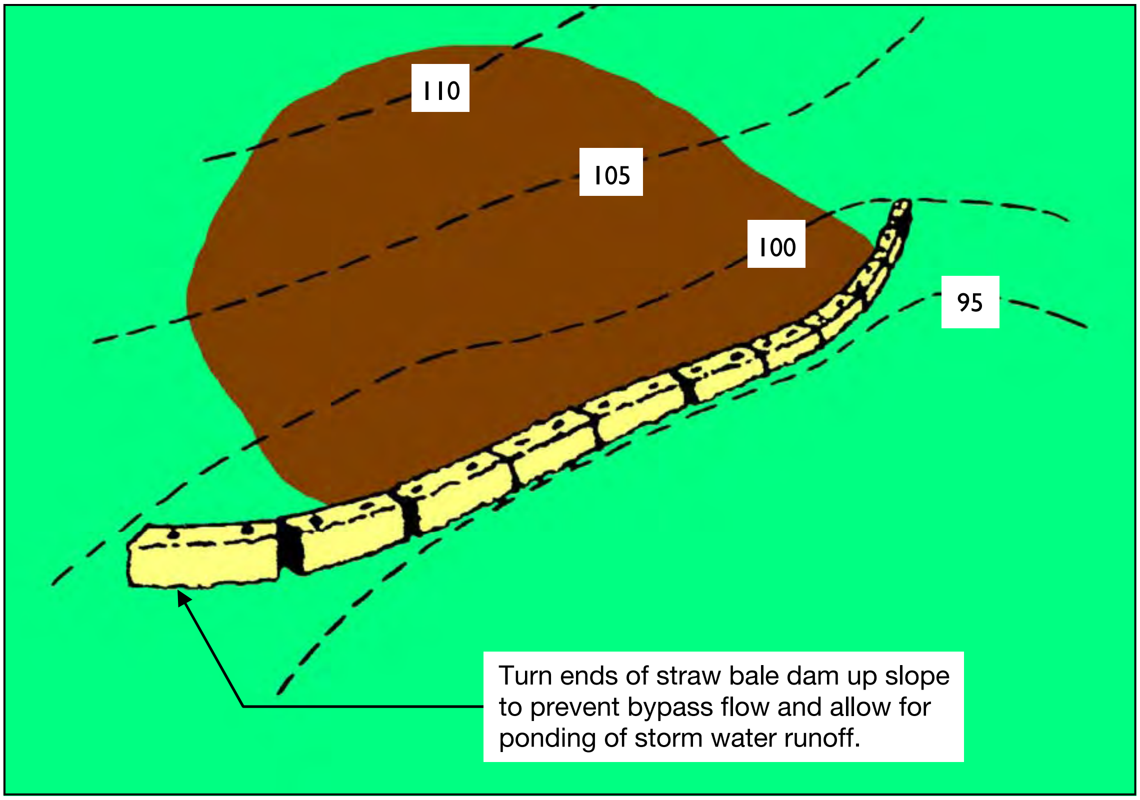
Installation

1. Lay out the location of the straw bale barrier so that it is parallel to the contour of the slope and at least 10 feet beyond the toe of the slope to provide a sediment storage area (see Exhibit 2). Turn the ends of the straw bale barrier up-slope such that the point of contact between the ground and the bottom of the straw bale barrier end terminates at a higher elevation than the top of the straw bale barrier at its lowest point (see Exhibit 1).
2. Excavate a trench at least four inches deep and one bale wide (see Exhibits 3 and 4).
3. Place each bale in the trench with the bindings oriented around the sides of the bale rather than on the top and bottom of the bale (to minimize deterioration of the bindings).
4. Abut each bale tightly against the preceding bale and anchor it in place by driving two anchor stakes through the bale. Drive the first stake toward the previously laid bale to force the bales together. Drive the stakes into the ground until the top of each stake is flush with the top of the bale.
5. Chink (tightly wedge) straw into any gaps between the bales to prevent sediment-laden water from running through.
6. Backfill the trench with excavated soil placed against the straw bales to ground level on the down-slope side and to four inches above ground level on the up-slope side of the straw bale barrier. Compact the fill material to keep it in place.

Maintenance

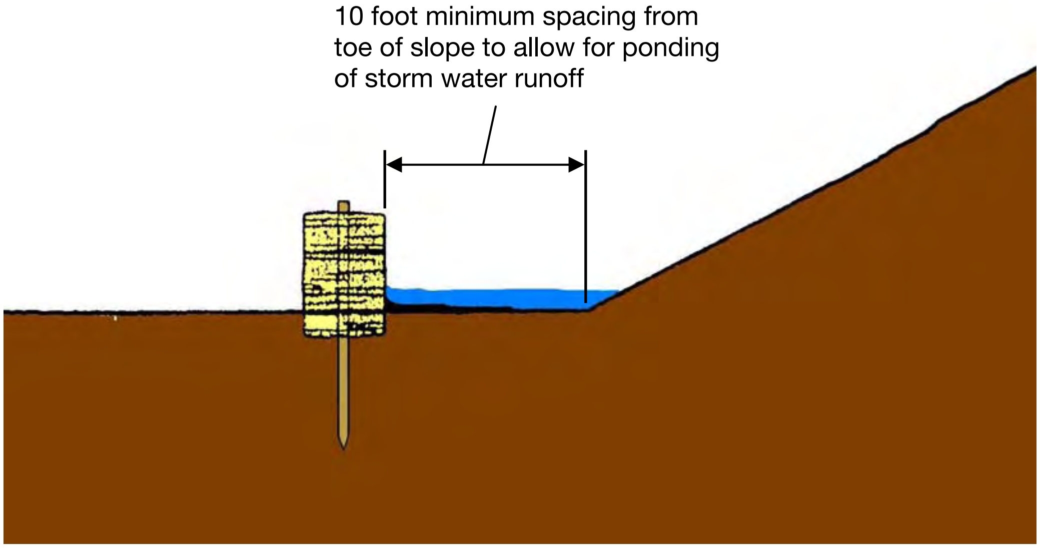
- Inspect within 24 hours of a rain event and at least once every seven calendar days.
- Remove sediment deposits promptly (to ensure adequate storage volume for the next rain), taking care not to undermine the entrenched bales.
- Inspect for deterioration or damage from construction activities; replace damaged bales immediately.
- When the contributing drainage area has been stabilized, remove all of the straw bales and sediment deposits, grade the site to blend with the surrounding area, and stabilize.

Exhibit 1



Source: Adapted from Minnesota Pollution Control Agency, Minnesota Construction Site Erosion and Sediment Control Planning Handbook, 1987

Exhibit 2



Source: California Regional Water Quality Control Board, San Francisco Bay Region Erosion and Sediment Control Field Manual, Second Edition

Exhibit 3

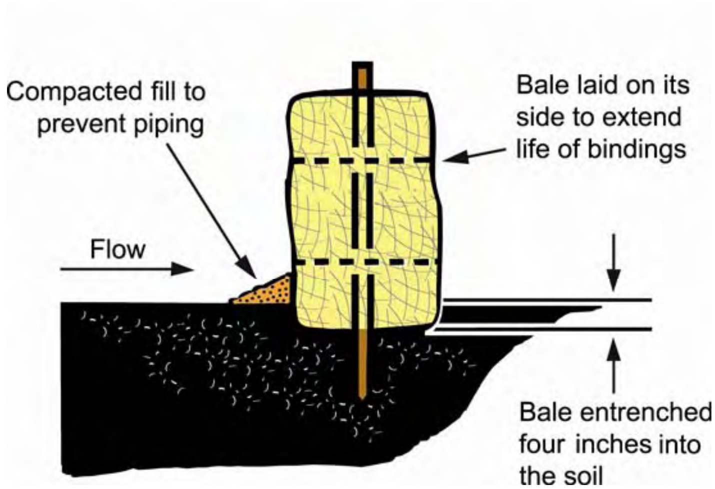
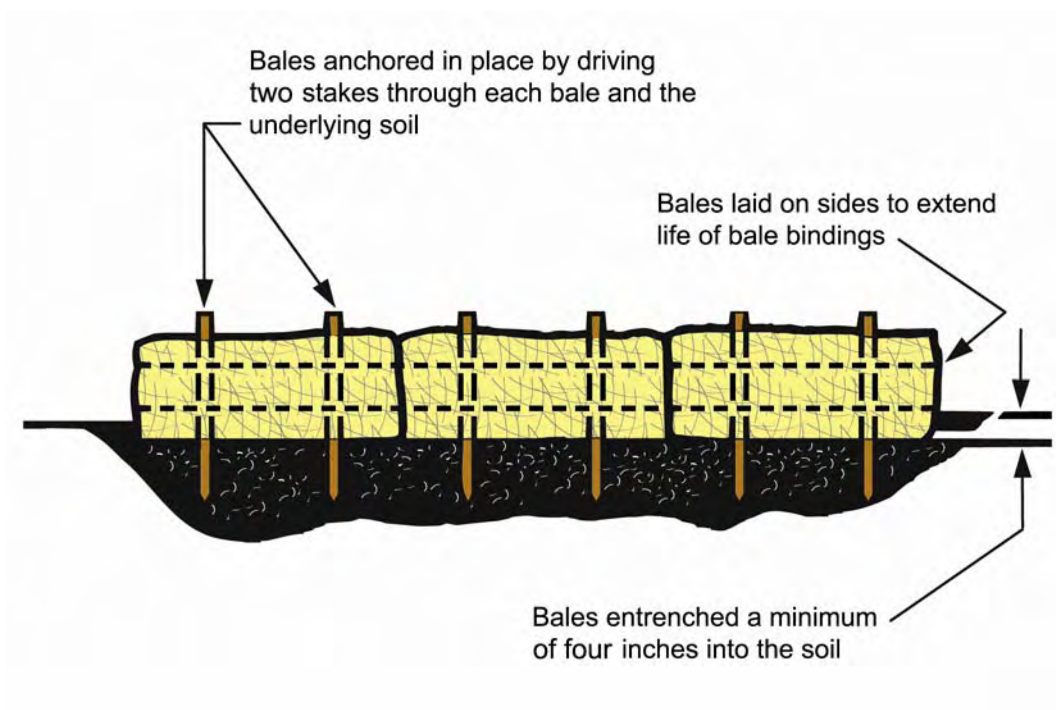


Exhibit 4



Filter Berm

Source: Rexius, Inc.

*A **filter berm** is a temporary barrier consisting of a compost ridge installed on the contour to intercept and treat sediment-laden storm water runoff from small, unvegetated drainage areas.*

Purpose

To trap sediment from small, disturbed areas by reducing velocity of sheet flow. Filter ridges capture sediment by filtering storm water runoff and by ponding water to allow settling and deposition.

Note: **A filter ridge is not recommended for use as a diversion and shall not be used across a stream, channel, ditch, swale, or anywhere that concentrated flow is anticipated.**

Specifications

Drainage Area

- Limited to one-quarter acre per 100 linear feet of ridge.
- Further restricted by slope steepness.

Table 1. Filter Ridge Size Requirements

Slope		**Maximum Distance Above Filter Ridge** (linear feet)	**Filter Ridge Minimum Size Requirements** (Width to Height Ratio of 2:1)
0% – 2%	< 50:1	100	2 ft x 1 ft
2% – 10%	50:1 to 10:1	75	2 ft x 1 ft
10% – 20%	10:1 to 5:1	50	2 ft x 1 ft
20% – 33%	5:1 to 3:1	25	2.6 ft x 1.3 ft
> 33%	> 3:1	15	3 ft x 1.5 ft

Location

- Installed on the contour.
- Five to 10 feet from toe of slope.
- Ends of filter ridge turned upslope so that base of ridge ends terminate at a higher elevation than the top of the berm at its lowest point.

Compost/Mulch Specifications

- Feedstocks may include but are not limited to well-composted vegetable matter, leaves, yard trimmings, food scraps, composted manures, paper fiber, wood bark, Class A biosolids (as defined in federal regulations 40 CFR Part 503), or any combination thereof.
- Compost shall be produced using an aerobic composting process meeting CFR 503 regulations, including time and temperature data indicating effective weed seed, pathogen and insect larvae kill.
- Compost shall be well decomposed, stable, and weed free.
- Variable particle size with maximum dimensions of three inches in length, one-half inch in width, and one-half inch in depth.
- Refuse free (less than one percent by weight).
- Free of any contaminants and materials toxic to plant growth.
- Inert materials not to exceed one percent by dry weight.
- pH of 5.5 to 8.0.
- Carbon-nitrogen ratio not to exceed 100.
- Moisture content not to exceed 45 percent by dry weight.

Bonding Agents

Tackifiers, flocculants, or microbial additives may be used to remove sediment and/or additional pollutants from storm water runoff. (All additives combined with compost materials should be tested for physical results at a certified erosion and sediment control laboratory and biologically tested for elevated beneficial microorganisms at a United States Compost Council, Seal of Testing Assurance, approved testing laboratory.)

Anchoring Method

Bonding agents per manufacturer's specifications.

Application

1. Remove existing vegetation, large soil clods, rocks, stumps, large roots, and debris in areas where filter ridge is to be constructed.
2. Construct the filter ridge. Use a pneumatic blower and three-wheeled ridge building machine or construct per manufacturer's directions. (Seed or sod may be applied at the time of installation for permanent applications.)

Maintenance

- Inspect within 24 hours of a rain event and at least once every seven calendar days.
- Remove accumulated sediment when it reaches one-quarter the height of the filter ridge.
- Inspect to ensure that the ridge is holding its shape and producing adequate flow.
- Repair eroded and damaged areas.
- If ponding becomes excessive, ridges should be removed and reconstructed.
- Reseed, if applicable.
- If the filter ridge is not designed as a permanent filter or part of the natural landscape and the contributing drainage area has been stabilized, use a bulldozer, loader, rake, or other device to remove the ridge, incorporate it into the soil, or spread it over the top of the soil surface for final seeding.

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Filter Tube/Filter Sock

*A **filter tube/filter sock** is a temporary barrier consisting of permeable material (i.e., aggregate, compost, excelsior, or straw, etc.) contained in a permeable geotextile fabric or non-biodegradable net matrix installed to intercept and treat sediment-laden runoff from small, unvegetated drainage areas.*

Purpose

To trap sediment by intercepting runoff and reducing the velocity of sheet flow or concentrated flow (limited application). Filter socks capture sediment by ponding water to allow settling and deposition.

Note: **A filter sock, unlike a filter ridge, may be used as a diversion and across shallow swales where concentrated flow is anticipated.**

Specifications

Drainage Area

- Limited to one-quarter acre per 100 linear feet of barrier.
- Further restricted by slope steepness.

Table 1. Filter Sock Size Requirements, Sheet Flow Application

Slope		**Maximum Distance Above Filter Sock** (linear feet) **for Minimum Filter Sock Sizes** (diameter of sock)			
		8 inch	12 inch	18 inch	24 inch
0% – 2%	< 50:1	125	250	300	350
2% – 10%	50:1 to 10:1	100	125	200	250
10% – 20%	10:1 to 5:1	75	100	150	200
20% – 33%	5:1 to 3:1	25	50	75	100
> 33%	> 3:1	10	25	50	75

Location

- Slope Application
  - Installed on the contour.
  - Five to 10 feet from toe of slope (10 feet preferred).
- Channel/Swale Application
  - Perpendicular to channel flow.
  - Less than one acre of drainage area.
  - Utilize larger product, typically 18 or more inches.
- Drop Inlet Protection
  - Refer to standards and principles contained in the **Temporary Drop Inlet Protection** section on page 143.
- Accessible for maintenance (removal of sediment and replacement if needed.

Materials

- Geotextile fabric sock or a non-biodegradable netting matrix.
- Specifications for permeable material:

Compost/Mulch Specifications

- Feedstocks may include, but are not limited to, well-composted vegetable matter, leaves, yard trimmings, food scraps, composted manures, paper fiber, wood bark, Class A biosolids (as defined in federal regulations 40 CFR Part 503), or any combination thereof.
- Compost shall be produced using an aerobic composting process meeting CFR 503 regulations, including time and temperature data indicating effective weed seed, pathogen and insect larvae kill.
- Compost shall be well decomposed, stable, and weed free.
- Variable particle size with maximum dimensions of two inches in length, one-half inch in width, and one-half inch in depth.

Table 2. Compost Particle Size

Percent Passing Sieve Size			
2-Inch Sieve	1-Inch Sieve	¾-Inch Sieve	¼-Inch Sieve
100%	99%	70%	25%

- Refuse free (less than one percent by weight).
- Free of any contaminants and materials toxic to plant growth.
- Inert materials not to exceed one percent by dry weight.
- pH of 5.5 to 8.0.
- Carbon-nitrogen ratio not to exceed 100.

- Moisture content not to exceed 45 percent by dry weight.

Aggregate Specification

- INDOT CA No. 5 or No. 8 aggregate.

Straw, Excelsior, etc. Specification

- Premanufactured.

Anchoring Method

- Posts - 2 x 2 inch hardwood or steel posts.

Bonding Agents (optional)

Tackifiers, flocculants, or microbial additives may be used to remove sediment and/or additional pollutants from storm water runoff. (All additives combined with compost materials should be tested for physical results at a certified erosion and sediment control laboratory and biologically tested for elevated beneficial microorganisms at a United States Compost Council, Seal of Testing Assurance approved testing laboratory.)

Installation

1. Lay out the location of the filter sock barrier so that it is parallel to the contour of the slope and at least 10 feet beyond the toe of the slope to provide a sediment storage area. Turn the ends of the filter sock barrier up slope such that the point of contact between the ground and the bottom of the filter sock barrier end terminates at a higher elevation than the top of the filter sock barrier at its lowest point.
2. Excavate a trench with a depth and width equal to at least one-fourth the diameter of the filter sock or follow the manufacturer's recommendations. Where applicable, the trench may also be excavated upslope of a curb or sidewalk. Placing the product against the curb or sidewalk will provide additional stability and resistance to surface flow.
3. Construct the filter sock or utilize a pre-manufactured product. For compost use a pneumatic blower or similar device to provide adequate and consistent fill in the sock. (Seed or sod may be applied at the time of installation for permanent applications.)
4. If more than one sock is placed in a row, the socks should be overlapped; not abutted.
5. Anchor the filter sock barrier in place by driving posts through the barrier and into the underlying soil material. Posts should be spaced no more than five feet apart and driven through the middle of the sock. The posts should

be driven a minimum of 18 inches deep into the soil. The stake should be flush with the top of the sock.

6. Backfill the trench with excavated soil placed against the filter sock barrier to ground level on the down-slope side and to two inches above ground level on the up-slope side of the filter sock barrier. Compact the fill material to keep it in place.

Options for Installation

- These products may be placed in a series on the contour at intervals on a slope.
  - Follow the manufacturer's recommendations for this application, including spacing and diameter of product.
  - This application will require careful layout and installation. Alternatives, including immediate stabilization, should be considered as the first alternative. This application also requires extensive maintenance and daily inspections.
  - Typical applications include:
    - Slopes less than 20 percent (5:1). Place socks at a maximum interval of 20 feet (a closer spacing is more effective).
    - Slopes between 20 percent (5:1) and less than 50 percent (2:1). Place socks at a maximum interval of 15 feet (a closer spacing is more effective).
    - Slopes greater than 50 percent (2:1). Place socks at a maximum interval of 10 feet (a closer spacing is more effective).

Maintenance

- Inspect within 24 hours of a rain event and at least once every seven calendar days. When installed in a series at intervals on a slope, inspection should be done daily.
- Remove accumulated sediment when it reaches one-quarter the height of the filter sock.
- Inspect to ensure that the sock is maintaining its integrity and producing adequate flow.
- Repair eroded and damaged areas.
- If ponding becomes excessive, socks should be removed and either reconstructed or new product installed.
- Reseed, if applicable.
- If the filter sock is not designed as a permanent filter or part of the natural landscape and the contributing drainage area has been stabilized, use a blade or knife to cut open sock and use a bulldozer, loader, rake, or other device to incorporate the organic material into the soil, or spread it over the top of the soil surface for final seeding. Remove and dispose of sock if necessary.

SITE MANAGEMENT MEASURES

Site management measures listed in this section of the manual have been designed to minimize pollutants associated with building materials and the operation and maintenance of mechanical equipment associated with construction activities. With a few exceptions, every measure listed in this section of the manual will be applicable to an active construction site.

The measures listed here address everything from controlling and managing sediment (both waterborne and airborne) associated with the operation of construction equipment to the proper storage and handling of materials associated with building and infrastructure construction.

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Dust Control

***Dust control** is a construction site management measure used to control the blowing and movement of dust on construction sites and associated land-disturbing activities. Dust control measures may consist of either chemical, structural, or mechanical measures.*

Purpose

To reduce wind-borne soil particles (dust) that may be transported and deposited in waterbodies, create a health hazard, and/or a visibility hazard.

Specifications

Site Management

- Dust control measures may be applied at any construction site, but should always be utilized for sites with dry, unvegetated soils that are exposed to wind or vehicle traffic that can potentially result in the generation of dust.
- Where practical, locate haul roads and stockpiles away from existing residential housing, businesses, and public areas.
- Limit construction equipment on haul roads to the extent practical. Construction equipment should maintain low speeds of 15 miles per hour or less.
- Trucks leaving a project site should be covered, especially where conditions may result in blowing of haul material.
- Minimize areas of disturbed, unvegetated soil exposed to traffic and wind.
- Water quality impacts should always be considered when selecting a dust control treatment.

Materials

- Temporary Methods –
  Select an appropriate method to reduce dust generation from haul roads, heavy traffic areas, paved roads, or large open areas of unvegetated land. A combination of appropriate methods will yield the best results.

  - Watering/Irrigation
    - Typically used for haul roads and heavy traffic areas.
    - Used as an emergency treatment measure.

  - Dust suppressants that are commercially available. Some products may be toxic to the environment. The level of toxicity and proximity to waterbodies and other unique resource areas should be considered when selecting a product. Products should be strictly applied according to the standards and specifications of the manufacturer and in accordance with applicable local, state, and federal regulations.

Chlorides

- Typically used for unpaved construction haul roads.
- Calcium Chloride (CaCl) and Magnesium Chloride (MgCl).
- Hygroscopic product that absorbs water.
- Applied as a liquid solution or dry granules/flakes.
- Apply and maintain in an environmentally safe manner.
- Application can inhibit plant growth.
- Runoff from treated areas can pollute waterbodies.

Resins

- Typically applied to haul roads, soil stockpiles, unvegetated soils, or used as a tackifier.
- Manufactured from petroleum, wood residue, or other chemicals.
- Bonds soil particles together.
- Water sheds off soils treated with these products.
- Low environmental impact after application.
- Avoid introducing resins into waterbodies during application.

Polymer Products (acrylic polymers and polymer emulsions)

- Typically used on soil stockpiles, unvegetated soils.
- May also be applicable to haul roads.
- Bonds soil particles together.
- Used to stabilize and/or seal soils.
- Apply with truck or hydroseeding machine.

- Use restricted to anionic polymer mixtures and shall have less than or equal to .05 percent free acrylamide monomer by weight as established by the U.S. Food and Drug Administration and the U.S. Environmental Protection Agency.

Ligninsulfonates

- Typically used for haul roads.
- Derived from wood pulp.
- Bonds soil particles, however retains some plasticity.
- Water soluble and could lose bonding capability in heavy rain.
- Environmentally friendly.

Tillage

- Large open disturbed areas.
- Used as an emergency treatment measure.
- Relatively flat areas of less than two percent.
- Chisel plows with shanks spaced 12 to 18 inches apart, straight-toothed harrows, or similar tillage equipment.
- Best if implemented before soil begins to blow.

Mulch (see **Mulching** on page 55)

- Disturbed areas.
- Effective, temporary measure.
- Fast and effective measure.

Temporary Vegetative Cover (see **Temporary Seeding** on page 31)

- Disturbed areas.
- Effective, temporary measure.

Physical Barriers

- Emergency treatment measure.
- Solid board fences, snow fences, burlap fences, crate walls, bales of hay, etc.
- Used to control air currents and soil migration.

Street Sweeping

- Paved areas.
- Maintenance measure.
- Street sweeper, vacuum truck, or a bucket end loader.

Nonerosive, Nonvegetative Soil Cover Measures

- ♦ For example, aggregate (see **Temporary Construction Ingress/Egress** on page 17), tarps, etc.

- Permanent Methods
  - Permanent vegetative cover (see **Permanent Seeding** on page 35 and **Tree Preservation and Protection** on page 13).
  - Preserve existing vegetation that is suitable to reducing blowing soil and diminishing wind velocity.

Application

Prepare site for the application method or product that was selected for dust control. For example, all haul roads should be bladed smooth with a crown or slope to avoid ponding and compacted as needed.

Watering

1. Sprinkle soil surface until soil is moist.
2. Apply at a rate to keep the soil moist/wet, but not saturated or muddy. Over watering may result in muddy conditions and a high potential for tracking of sediment off-site by vehicle tires/tracks.
3. Reapply as required. Constant repetition is required for effective control. Frequency will be dependent on soil type and construction traffic.

Commercially Available Dust Suppressants

Includes chlorides (calcium and magnesium), resins, polymer products, and ligninsulfonates.

1. Apply according to the standards and specifications of the manufacturer and in accordance with all applicable local, state, and federal regulations.
2. Prepare site for application.
3. Apply and maintain according to the recommendation of the manufacturer.

Mulch

1. Apply mulch and anchor in place by crimping or applying a tackifier (see **Mulching** on page 55).

Temporary Vegetative Cover

1. Prepare seedbed, seed, and apply mulch. Mulch should be anchored in place (see **Temporary Seeding** on page 31 and **Mulching** on page 55).

Physical Barriers

1. Select an appropriate barrier for site conditions.
2. Place the barrier or barriers at right angles to the prevailing winds at intervals of approximately 10 times the height of the barrier.

Street Sweeping

1. Choose a method that does not generate large amounts of dust. Rotary brushes fixed to the front of equipment may just resuspend dust particles.
2. Clear sediment from the paved area.
3. Dispose of all cleared material properly so that is not redeposited in the street.

Tillage

1. Best if implemented before soil begins to blow.
2. Tillage should begin on the windward side of the site and leave six-inch furrows, preferably perpendicular to the prevailing wind direction to gain the greatest reduction.
3. Roughen the soil surface to bring clods to the surface.

Maintenance

- Inspect daily.
- Repeat treatments as needed when using temporary dust control methods.
- Commercial products should be used in accordance with the recommendations of the manufacturer.

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Vehicle Wash Pads

To be released at a later time

Concrete Washout

***Concrete washout** areas are designated locations within a construction site that are either a prefabricated unit or a designed measure that is constructed to contain concrete washout. Concrete washout systems are typically used to contain washout water when chutes and hoppers are rinsed following delivery.*

Purpose

Concrete washout systems are implemented to reduce the discharge of pollutants that are associated with concrete washout waste through consolidation of solids and retention of liquids. Uncured concrete and associated liquids are highly alkaline which may leach into the soil and contaminate ground water or discharge to a waterbody or wetland which can elevate the pH and be harmful to aquatic life. Performing concrete washout in designated areas and into specifically designed systems reduces the impact concrete washout will have on the environment.

Specifications

Site Management

- Complete construction/installation of the system and have washout locations operational prior to concrete delivery.
- Do not wash out concrete trucks or equipment into storm drains, wetlands, streams, rivers, creeks, ditches, or streets.
- Never wash out into a storm sewer drainage system. These systems are typically connected to a natural conveyance system.
- Where necessary, provide stable ingress and egress (see **Temporary Construction Ingress/Egress Pad** on page 17).
- It is recommended that washout systems be restricted to washing concrete from mixer and pump trucks and not used to dispose of excess concrete or

residual loads due to potential to exceed the design capacity of the washout system. Small amounts of excess or residual concrete (not washout water) may be disposed of in areas that will not result in flow to an area that is to be protected.

- Install systems at strategic locations that are convenient and in close proximity to work areas and in sufficient number to accommodate the demand for disposal.
- Install signage identifying the location of concrete washout systems.

Location

- Locate concrete washout systems at least 50 feet from any creeks, wetlands, ditches, karst features, or storm drains/manmade conveyance systems.
- To the extent practical, locate concrete washout systems in relatively flat areas that have established vegetative cover and do not receive runoff from adjacent land areas.
- Locate in areas that provide easy access for concrete trucks and other construction equipment.
- Locate away from other construction traffic to reduce the potential for damage to the system.

General Design Considerations

- The structure or system shall be designed to contain the anticipated washout water associated with construction activities.
- The system shall be designed, to the extent practical, to eliminate runoff from entering the washout system.
- Runoff from a rainstorm or snowmelt should not carry wastes away from the washout location.
- Washout will not impact future land uses (i.e., open spaces, landscaped areas, home sites, parks).
- Washout systems/containment measures may also be utilized on smaller individual building sites. The design and size of the system can be adjusted to accommodate the expected capacity.

Prefabricated Washout Systems/Containers

- Self-contained sturdy containment systems that are delivered to a site and located at strategic locations for concrete disposal.

- These systems are manufactured to resist damage from construction equipment and protect against leaks or spills.
- Manufacturer or supplier provides the containers. The project site manager maintains the system or the supplier provides complete service that includes maintenance and disposal.
- Units are often available with or without ramps. Units with ramps lend themselves to accommodate pump trucks.
- Maintain according to the manufacturer's recommendations.

Designed and Installed Units

These units are designed and installed on site. They tend to be less reliable than prefabricated systems and are often prone to failure. Concrete washout systems can be constructed above or below grade. It is not uncommon to have a system that is partly below grade with an additional containment structure above grade.

- Washout systems shall utilize a pit or bermed area designed and maintained at a capacity to contain all liquid and concrete waste generated by washout operations.
- The volume of the system must also be designed to contain runoff that drains to the system and rainfall that enters the system for a two-year frequency, 24-hour storm event.

■ Below Grade System

- ♦ A washout system installed below grade should be a minimum of ten feet wide by ten feet long, but sized to contain all liquid and waste that is expected to be generated between scheduled cleanout periods. The size of the pit may be limited by the size of polyethylene available. The polyethylene lining should be of adequate size to extend over the entire excavation.
- ♦ Include a minimum 12-inch freeboard to reasonably ensure that the structure will not overtop during a rain event.
- ♦ Line the pit with ten millimeter polyethylene lining to control seepage.
- ♦ The bottom of excavated pit should be above the seasonal high water table.

■ Above Grade System

- ♦ A system designed and built above grade should be a minimum of ten feet wide by ten feet long, but sized to contain all liquid and waste that is expected to be generated between scheduled cleanout periods. The size of the containment system may be limited by the size of polyethylene available. The polyethylene lining should be of adequate size to extend over the berm or containment system.

- The system design may utilize an earthen berm, straw bales, sandbags, or other acceptable barriers that will maintain its shape and integrity and support the polyethylene lining.
- Include a minimum four-inch freeboard as part of the design.

Washout Procedures

- Do not leave excess mud in the chutes or hopper after the pour. Every effort should be made to empty the chutes and hopper at the pour. The less material left in the chutes and hopper, the quicker and easier the cleanout. Small amounts of excess concrete (not washout water) may be disposed of in areas that will not result in flow to an area that is to be protected.
- At the washout location, scrape as much material from the chutes as possible before washing them. Use non-water cleaning methods to minimize the chance for waste to flow off site.
- Remove as much mud as possible when washing out.
- Stop washing out in an area if you observe water running off the designated area or if the containment system is leaking or overflowing and ineffective.
- Do not back flush equipment at the project site. Back flushing should be restricted to the plant as it generates large volumes of waste that more than likely will exceed the capacity of most washout systems. If an emergency arises, back flush should only be performed with the permission of an on-site manager for the project.
- Do not use additives with wash water. Do not use solvents or acids that may be used at the target plant.

Materials

- Minimum of ten millimeter polyethylene sheeting that is free of holes, tears, and other defects. The sheeting selected should be of an appropriate size to fit the washout system without seams or overlap of the lining **(designed and installed systems)**.
- Signage.
- Orange safety fencing or equivalent.
- Straw bales, sandbags (bags should be ultraviolet-stabilized geotextile fabric), soil material, or other appropriate materials that can be used to construct a containment system **(above grade systems)**.

- Metal pins or staples at a minimum of six inches in length, sandbags, or alternative fastener to secure polyethylene lining to the containment system.
- Non-collapsing and non-water holding cover for use during rain events (optional).

Installation

Prefabricated Washout Systems/Containers

- Install and locate according to the manufacturer's recommendations.

Designed and Installed Systems

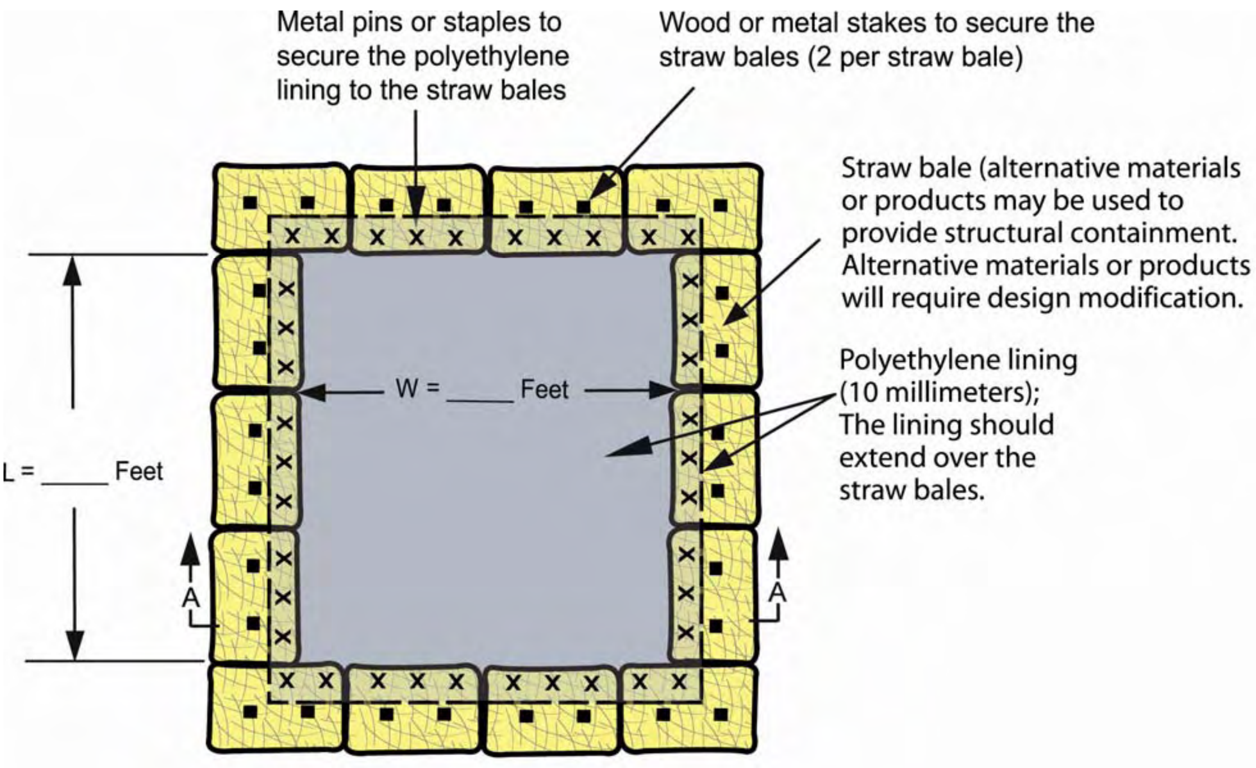
- Utilize and follow the design in the storm water pollution prevention plan to install the system.
- Dependent upon the type of system, either excavate the pit or install the containment system.
- A base shall be constructed and prepared that is free of rocks and other debris that may cause tears or punctures in the polyethylene lining.
- Install the polyethylene lining. For excavated systems, the lining should extend over the entire excavation. The lining for bermed systems should be installed over the pooling area with enough material to extend the lining over the berm or containment system. The lining should be secured with pins, staples, or other fasteners.
- Place flags, safety fencing, or equivalent to provide a barrier to construction equipment and other traffic.
- Place a non-collapsing, non-water holding cover over the washout facility prior to a predicted rainfall event to prevent accumulation of water and possible overflow of the system (optional).
- Install signage that identifies concrete washout areas.
- Post signs directing contractors and suppliers to designated locations.
- Where necessary, provide stable ingress and egress (see **Temporary Construction Ingress/Egress Pad** on page 17) or alternative approach pad for concrete washout systems.

Maintenance

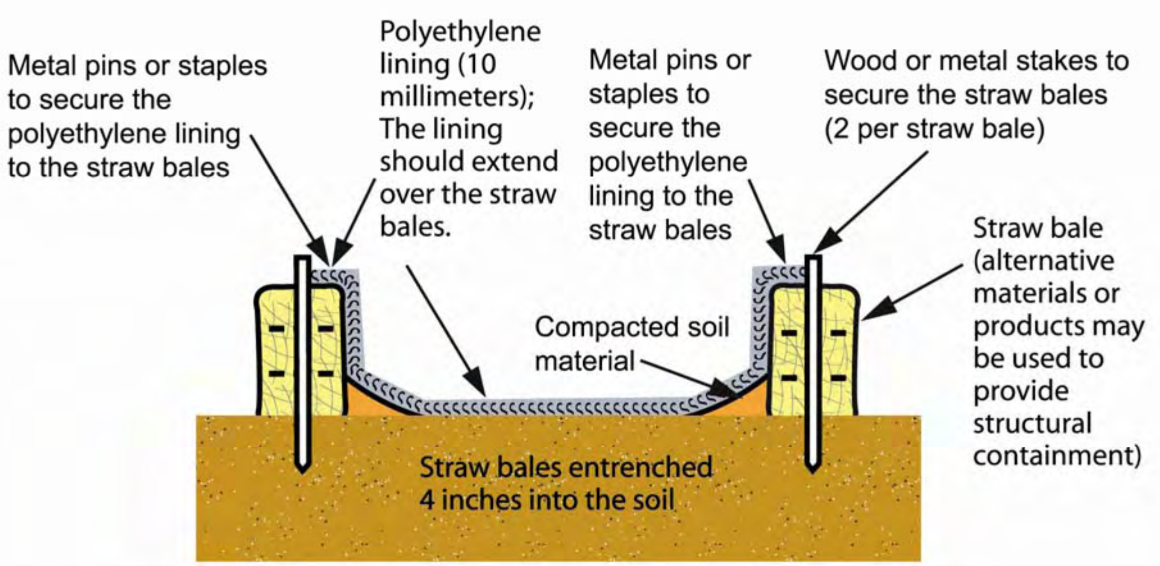
- Inspect daily and after each storm event.
- Inspect the integrity of the overall structure including, where applicable, the containment system.
- Inspect the system for leaks, spills, and tracking of soil by equipment.
- Inspect the polyethylene lining for failure, including tears and punctures.
- Once concrete wastes harden, remove and dispose of the material.
- Excess concrete should be removed when the washout system reaches 50 percent of the design capacity. Use of the system should be discontinued until appropriate measures can be initiated to clean the structure. Prefabricated systems should also utilize this criterion, unless the manufacturer has alternate specifications.
- Upon removal of the solids, inspect the structure. Repair the structure as needed or construct a new system.
- Dispose of all concrete in a legal manner. Reuse the material on site, recycle, or haul the material to an approved construction/demolition landfill site. Recycling of material is encouraged. The waste material can be used for multiple applications including but not limited to roadbeds and building. The availability for recycling should be checked locally.
- The plastic liner should be replaced after every cleaning; the removal of material will usually damage the lining.
- The concrete washout system should be repaired or enlarged as necessary to maintain capacity for concrete waste.
- Concrete washout systems are designed to promote evaporation. However, if the liquids do not evaporate and the system is near capacity it may be necessary to vacuum or remove the liquids and dispose of them in an acceptable method. Disposal may be allowed at the local sanitary sewer authority provided their National Pollutant Discharge Elimination System permits allow for acceptance of this material. Another option would be to utilize a secondary containment system or basin for further dewatering.
- Prefabricated units are often pumped and the company supplying the unit provides this service.
- Inspect construction activities on a regular basis to ensure suppliers, contractors, and others are utilizing designated washout areas. If concrete waste is being disposed of improperly, identify the violators and take appropriate action.

- When concrete washout systems are no longer required, the concrete washout systems shall be closed. Dispose of all hardened concrete and other materials used to construct the system.
- Holes, depressions and other land disturbances associated with the system should be backfilled, graded, and stabilized.

Concrete Washout (Above Grade System) Worksheet

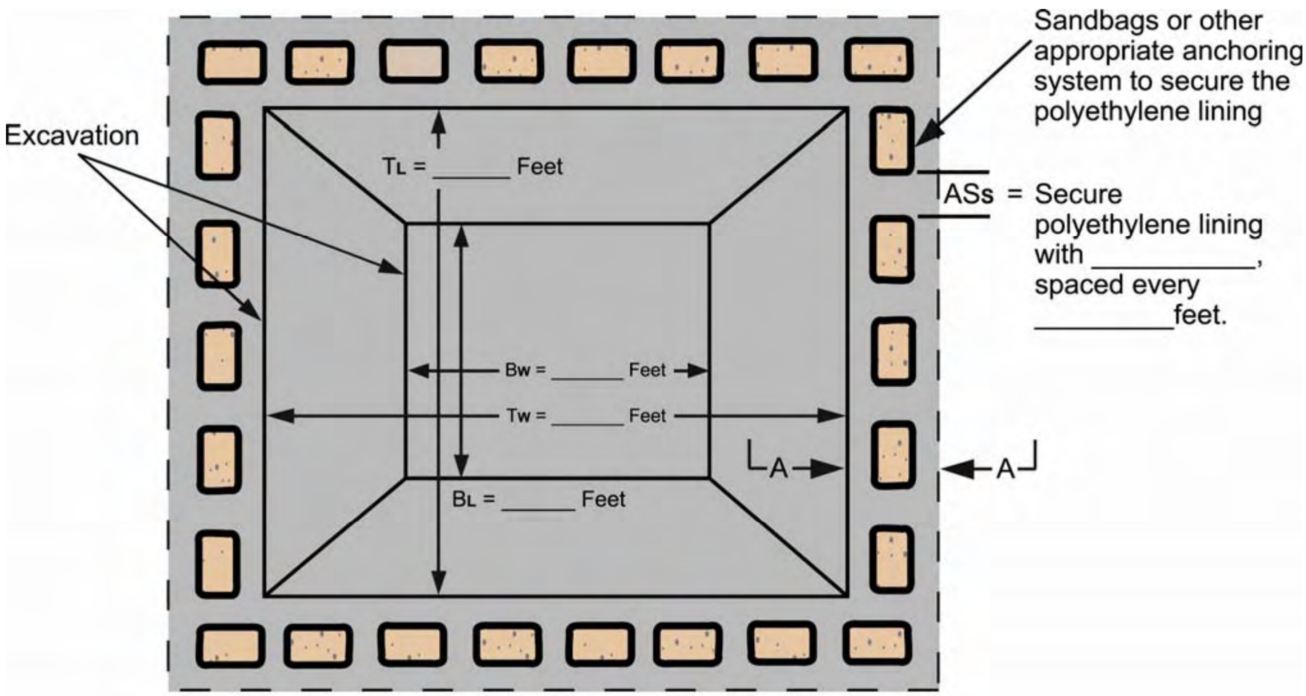


Plan View
Not to Scale



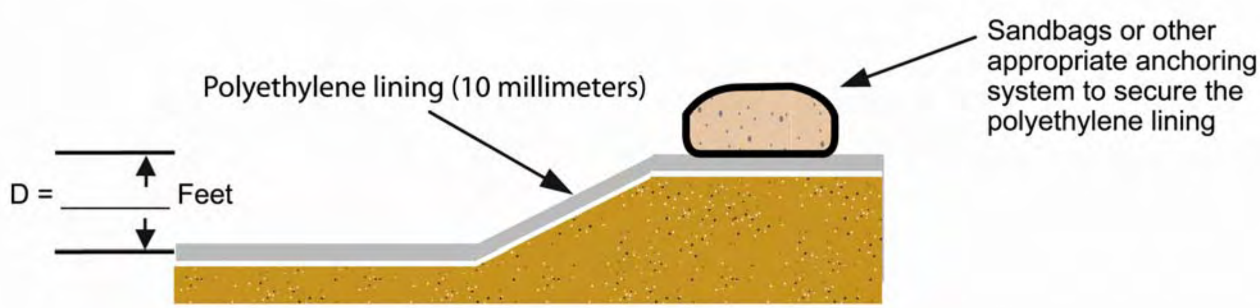
Section A-A
Not to scale

Concrete Washout (Below Grade System) Worksheet



TL = Top Length of Excavation
BL = Bottom Length of Excavation
Tw = Top Width of Excavation
Bw = Bottom Width of Excavation
ASs = Anchoring System type and spacing

Plan View
Not to Scale



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Equipment Maintenance & Fueling

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Storage & Handling of Materials

Source: John South, Hamilton County Soil and Water Conservation District

To be released at a later time

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STREAMBANK & SHORELINE STABILIZATION

Streambanks and shorelines often become unstable when adjacent areas undergo urban development. This is generally the result of property owners removing vegetative growth to improve aesthetic views and increased wave action from watercraft using the channel or water-body.

Stabilization of banks and shorelines may require an operator to work in the channel or lake. There are specific measures listed in the **Channel & Lake Operations & Measures** section on pages 265–290 that may be applicable to these work activities.

Whenever construction activities are being performed adjacent to or in a channel or lake, permits may by required. It is the responsibility of all parties to obtain the appropriate permits before commencing any work.

Designs for streambank and shoreline stabilization can be complex and require detailed site investigations and the application of sound engineering principles. A professional knowledgeable of these applications and experienced in design should be consulted when using these measures.

Specific measures related to streambank and shoreline stabilization can be found in the Indiana Drainage Handbook available from the Indiana Department of Natural Resources, Division of Water.

Sea Walls

To be released at a later time

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CHANNEL & LAKE OPERATIONS & MEASURES

Channel bank and shoreline erosion potential and off-site sedimentation is extremely high when land-disturbing activities are conducted in and around drainage channels and water-bodies. When feasible, every effort should be made to keep construction equipment out of the channel or waterbody.

Measures such as the temporary stream crossings listed in this section of the manual are designed to minimize contact between vehicular tires and tracks and channel banks/waterbody shorelines. Unfortunately, this is not always practical.

When construction activity must occur in a channel or waterbody, it is extremely important to isolate the work area using measures such as cofferdams and/or pump around/work isolation measures. Other measures such as floating turbidity barriers have been designed to slow water current flow and allow suspended soil particles to settle out.

Whenever work activities are being performed adjacent to/or within a channel or lake, permits may be required. It is the responsibility of all parties to obtain the appropriate permits before commencing any work.

Designs for channel or lake operations can be complex and require detailed site investigations and the application of sound engineering principles. A professional knowledgeable in these applications and experienced in design should be consulted when using these measures.

Additional measures related to work associated with channel and lake operations can be found in the Indiana Drainage Handbook available from the Indiana Department of Natural Resources, Division of Water.

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Temporary Stream Crossing — Bridges

*A **temporary bridge structure** is a crossing installed across a stream or watercourse for short-term use by construction vehicles or heavy equipment.*

Purpose

To provide a means of moving construction vehicles across a stream with minimal impact to the stream.

Notes:

1. **Bridges are preferable to other types of stream crossings because they cause the least disturbance to the stream.**
2. **Stream and riparian areas should be left in an undisturbed state to the greatest extent practical. Stream crossings should be installed for the shortest practical period of time and removed as soon as their function is completed because they generally constrict channel flow. During periods of high flow this can result in flooding of upstream areas and a high potential for washout of the structure which may result in downstream property damage.**

Specifications

Design Considerations

- Use where channels are narrow and/or deep.
- Do not construct during periods of fish spawning.
- In some instances it may be necessary to divert or isolate channel flow (see **Pump Around/Work Isolation** on page 289) during construction and removal of the stream crossing.

Anticipated Life

Generally less than one year.

Flow Capacity

Bank-full flow or peak discharge from a two-year frequency, 24-hour duration storm event without bank overflow (whichever is less).

Overflow Areas

Protected from erosion from a 10-year frequency, 24-hour duration storm event.

Discharge Velocity at Crossing Outlet

Nonerosive for the stream channel.

Permits

One or more permits may be needed from federal, state, or local permitting agencies. Note: **Allow sufficient time for obtaining the appropriate permits.**

Crossing Location

- Locate crossing where it will cause the least amount of disturbance to the channel and surrounding vegetation. (Good locations generally include straight, shallow sections of the channel rather than channel bends and deep pool areas.)
- Install crossing perpendicular to stream flow if feasible.

Road Approaches

- Where feasible, align the first 30 to 50 feet of approach road perpendicular to channel flow. (This provides for minimal disturbance to the riparian buffer and eliminates tight turns for construction equipment, thereby reducing the potential for erosion and sediment damage to the stream.)
- Minimize erosion potential by covering with INDOT No. 2 aggregate.
- Place geotextile underlayment under aggregate if soils are soft or if area will be subject to heavy use and heavy loads. (This provides a nonerosive surface, minimizes sediment-laden storm water runoff to the stream, and reduces the potential of vehicular tracking of sediment into the stream.)

Structure

- Does not create a flooding or safety hazard.
- Strong enough to accommodate expected load (size/weight).

Materials

- INDOT CA No. 2 aggregate.
- Geotextile fabric underlayment (optional).

Installation/Removal

Stream crossings should be as narrow as practical and streambank vegetation should be preserved to the maximum extent practical.

Installation

1. Where applicable, divert storm water runoff away from roadway approaches and into well-vegetated areas, temporary sediment traps (see **Temporary Sediment Trap** on page 183), or an appropriate sediment control measure. Storm water runoff from the roadway should not discharge directly into the stream (see Exhibit 1).

2. Where applicable, divert or isolate channel flow (see **Pump Around/Work Isolation** on page 289) before starting construction of the stream crossing.

3. Cut vegetation at locations used for approach road ramps, bridge crossing, and installation of nonvegetative sediment trapping devices. **Do not** grub the stumps or root systems. (The root systems help stabilize the streambanks and can help accelerate revegetation of the area.) Remove all logs, limbs, and loose debris from the work area and dispose of materials in pre-approved areas located outside the limits of the floodplain.

4. Elevate bridge abutments at least 12 inches above the adjoining streambank to allow storm water overflow to bypass the structure without damage.

5. Construct or install the bridge as specified in the construction plans.

6. Immediately stabilize all disturbed streambanks, roadway approaches, and other disturbed areas. Stabilize with appropriate permanent vegetative stabilization measures or an appropriate nonerosive armor (see **Surface Stabilization** on page 29).

Removal

1. Remove temporary bridges, including associated materials and debris.

2. Restore the channel to its original cross section or as specified by the requirements of any applicable permits.

3. Immediately stabilize or armor streambanks with an appropriate stabilization measure (see **Erosion Control Blanket** on page 63; **Turf Reinforcement Mat** on page 65; and **Riprap** on page 69) or appropriate bioengineering techniques and where applicable in accordance with permit requirements.

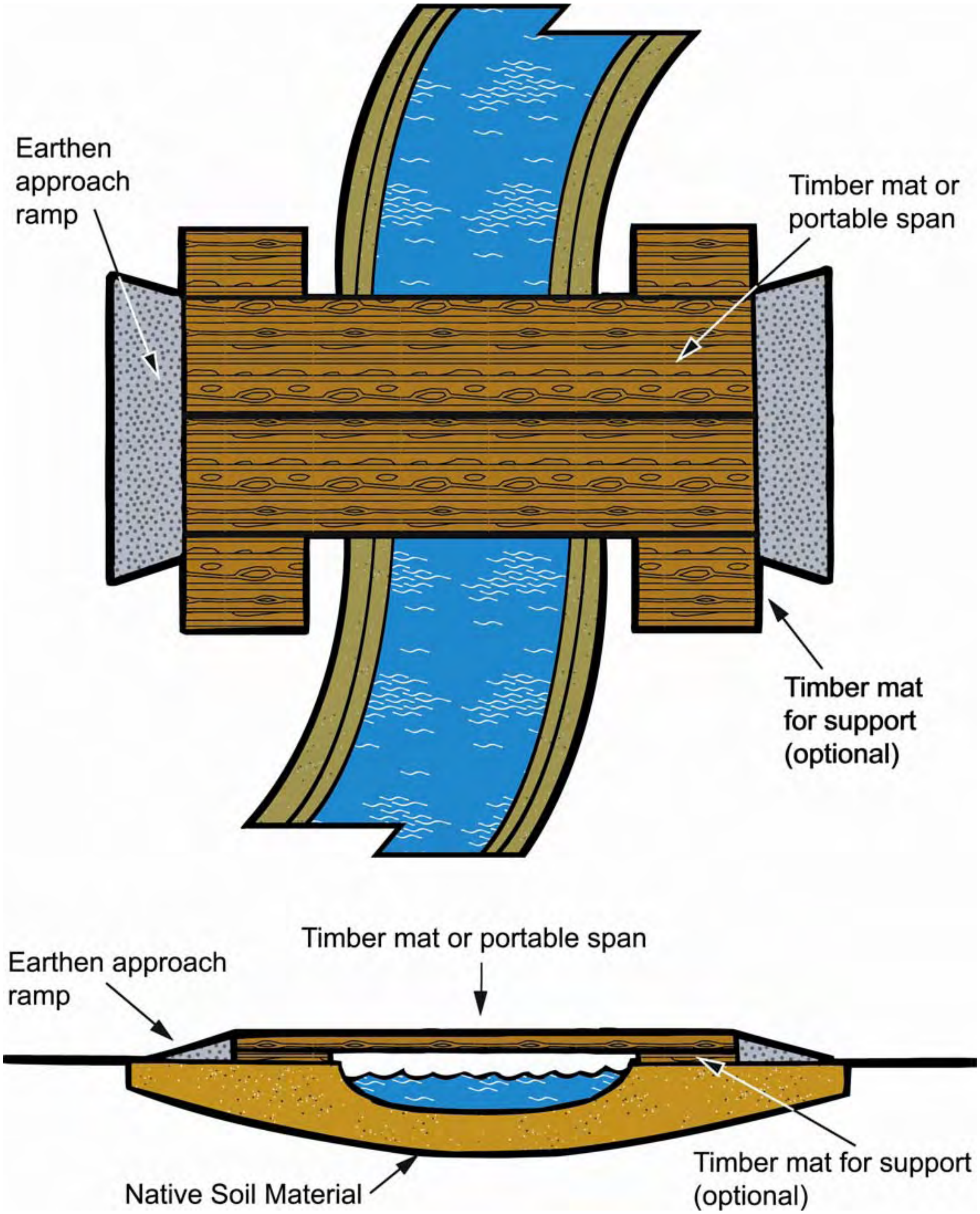
4. Fill road approaches. Over fill by 10 percent to allow for settling.

5. Permanently stabilize all disturbed streambanks, roadway approaches, temporary roadways and other disturbed areas. Stabilize with appropriate permanent vegetative stabilization measures or an appropriate nonerosive armor (see **Surface Stabilization** on page 29).

Maintenance

- Inspect within 24 hours of a rain event and at least once every seven calendar days.
- Check for accumulation of debris and obstructions such as limbs, logs, trash, rock, etc. around bridge abutments and bridge span areas; remove immediately.
- Inspect for erosion of streambanks and banks of approach road; repair immediately.
- Check for erosion or damage to abutments and repair immediately.

Exhibit 1



Note: This measure requires the designer to provide design specifications and dimensions.

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Temporary Stream Crossing — Culverts

*A **temporary culvert structure** is a crossing installed in a stream or watercourse for short-term use by construction vehicles or heavy equipment.*

Purpose

To provide a means of moving construction vehicles across a stream with minimal impact to the stream.

Notes:

1. **Culvert stream crossings are preferred over ford stream crossings because they only disturb the stream during structure installation and removal.**
2. **Stream and riparian areas should be left in an undisturbed state to the greatest extent practical. Stream crossings should be installed for the shortest practical period of time and removed as soon as their function is completed because they generally constrict channel flow. During periods of high flow this can result in flooding of upstream areas and a high potential for washout of the structure which may result in downstream property damage.**

Specifications

Design Considerations

- Use where wide-channel streams need to be crossed.
- Use where loads may be too heavy for bridge crossings.
- Do not construct during periods of fish spawning.
- In some instances it may be necessary to divert or isolate channel flow (see **Pump Around/Work Isolation** on page 289) during construction and removal of the stream crossing.

Anticipated Life

Generally less than one year.

Flow Capacity

Bank-full flow or peak discharge from a two-year frequency, 24-hour duration storm event without overflow (whichever is less).

Overflow Areas

Protected from erosion from a 10-year frequency, 24-hour duration storm event.

Discharge Velocity at Crossing Outlet

Nonerosive for the stream channel.

Permits

One or more permits may be needed from federal, state, or local permitting agencies. Note: **Allow sufficient time for obtaining the appropriate permits.**

Crossing Location

- Locate crossing where it will cause the least amount of disturbance to the channel and surrounding vegetation. (Good locations generally include straight, shallow sections of the channel rather than channel bends and deep pool areas.)
- Install crossing perpendicular to stream flow if feasible.

Road Approaches

- Where feasible, align first 30 to 50 feet of approach road perpendicular to channel flow. (This provides for minimal disturbance to the riparian buffer and eliminates tight turns for construction equipment, thereby reducing the potential for erosion and sediment damage to the stream.)
- Minimize erosion potential by covering with INDOT No. 2 aggregate.
- Place geotextile underlayment under aggregate if soils are soft or if area will be subject to heavy use and heavy loads. (This provides a nonerosive surface, minimizes sediment-laden storm water runoff to the stream, and reduces the potential of vehicular tracking of sediment into the stream.)

Structure

- Stable and non-erosive [clean, non-sediment producing material (i.e., no earth fill in the stream channel)].
- Must not create a flooding or safety hazard.
- Strong enough to accommodate expected load (size/weight).

Materials

- INDOT revetment riprap or larger (used as construction fill within the waterway channel).
- INDOT CA No. 2 aggregate or larger (for vehicular driving surface).
- Geotextile fabric.
- Culvert
  - Material – reinforced concrete, corrugated metal, structural plate.
  - Shape – circular, arched, or oval.
  - Size – largest pipe diameter that will fit into the existing channel without major approach fills.
  - Length – maximum length of 40 feet.
  - Strength – strong enough to support the cross section of the pipe for the maximum loads expected.
- Anchor cable.

Installation/Removal

Stream crossings should be as narrow as practical and streambank vegetation should be preserved to the maximum extent practical.

Installation

1. Where applicable, divert storm water runoff away from roadway approaches and into well-vegetated areas, temporary sediment traps (see **Temporary Sediment Trap** on page 183), or an appropriate sediment control measure. Storm water runoff from the roadway should not discharge directly into the stream (see Exhibit 1).

2. Where applicable, divert or isolate channel flow (see **Pump Around/Work Isolation** on page 289) before starting construction of stream crossing.

3. Cut vegetation at locations used for approach roads, culvert installation, and installation of non-vegetative sediment trapping devices. **Do not** grub the stumps or root systems (the root systems help stabilize the streambanks and can help accelerate revegetation of the area). Remove all logs, limbs, and loose debris from the work area and dispose of materials in pre-approved areas located outside the limits of the floodplain.

4. Remove boulders and debris in the area of the planned culvert installation. Also remove debris that can easily be carried downstream and block culverts.

5. Place geotextile fabric on the streambed and streambanks.

6. Install culvert pipes with the invert elevation at the same elevation as the streambed to prevent obstruction of stream flow and fish passage.

7. Anchor the culvert pipe in place with anchor cables and anchor stakes (to prevent floating of the pipe during high channel flow).

8. Cover the culvert pipe with riprap (use as construction fill within the waterway channel).

9. Place a minimum of 12 inches of INDOT CA No. 2, or larger, aggregate over the riprap (for vehicular driving surface). If multiple culvert pipes are used, they need to be separated by 12 inches of compacted aggregate fill. Only clean aggregate should be placed in the stream channel. **DO NOT** use fill materials other than clean stone. Culvert pipe ends must extend a minimum of 12 inches beyond the ends of the aggregate fill slope.

10. Divert storm water runoff away from roadway approaches and into well vegetated areas or temporary sediment traps (see **Temporary Sediment Trap** on page 183). Storm water runoff from the roadway should not discharge directly into the stream.

11. Immediately stabilize all disturbed streambanks, roadway approaches, and other disturbed areas. Stabilize with appropriate permanent vegetative stabilization measures or an appropriate nonerosive armor (see **Surface Stabilization** on page 29).

Removal

1. Remove culverts, including associated materials and debris. Clean aggregate can be left in the channel as long as it does not impede stream flow, increase flooding risk, or obstruct fish migration. (Removal of aggregate from the channel generally results in significant disturbance of the streambed and streambank, in temporary clouding of the stream, and damage to aquatic habitat.)

2. Restore the channel to its original cross section or as specified by the requirements of any applicable permits.

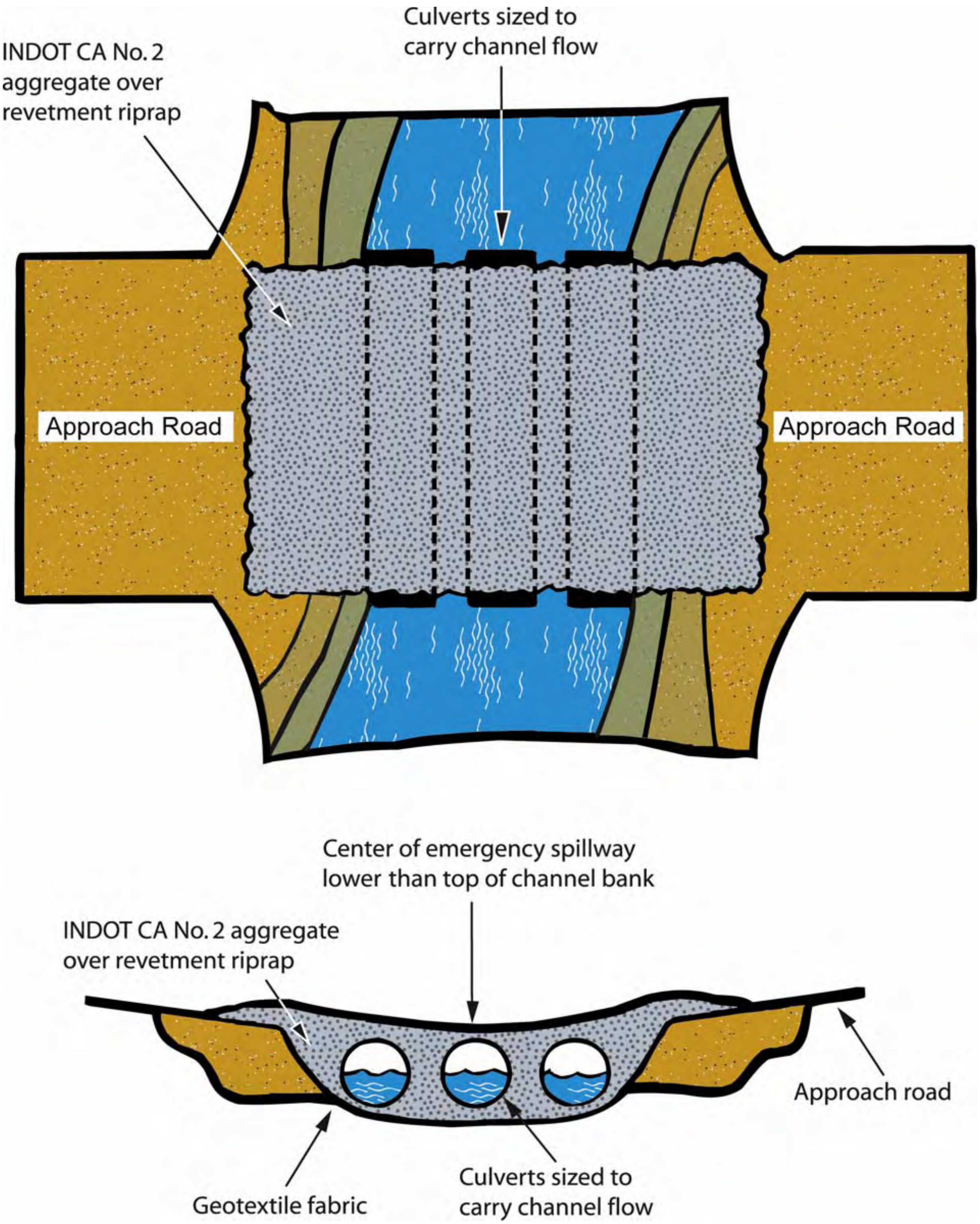
3. Where applicable, fill road approaches. Overfill by 10 percent to allow for settling.

4. Permanently stabilize all disturbed streambanks, roadway approaches, temporary roadways and other disturbed areas. Stabilize with appropriate permanent vegetative stabilization measures or an appropriate nonerosive armor (see **Surface Stabilization** on page 29).

Maintenance

- Inspect within 24 hours of a rain event and at least once every seven calendar days.
- Check for accumulation of debris and obstructions such as limbs, logs, trash, rock, etc. around culvert pipe inlets; remove immediately.
- Check for erosion of streambank and banks of approach roads/ramps; repair immediately.
- Check for piping along culverts; repair immediately.
- Check for sediment accumulation in aggregate materials; remove and replace with clean aggregate. Note: Do not apply clean aggregate over existing sediment-laden aggregate.
- Repair any damage or displacement of aggregate.

Exhibit 1



Note: This measure requires the designer to provide design specifications and dimensions.

Temporary Stream Crossing — Fords

Source: U.S. Department of Agriculture, Natural Resources Conservation Service

A ***ford*** *is a temporary stone structure installed across a stream or watercourse for short-term use by construction vehicles or heavy equipment.*

Purpose

To provide a means of moving construction vehicles across a stream with minimal impact to the stream.

Notes:

1. **Fords are the least desirable type of stream crossing because vehicles must drive through the channel, causing clouding of the stream with each crossing.**
2. **Tires and tracks of vehicles crossing a ford should be free of mud prior to entering the channel.**
3. **Stream and riparian areas should be left in an undisturbed state to the greatest extent practical.**

Specifications

Design Considerations

- Use where very little construction traffic is anticipated.
- Use in channels with a streambank height of five feet or less.
- Do not construct during periods of fish spawning.
- In some instances it may be necessary to divert or isolate channel flow (see **Pump Around/Work Isolation** on page 289) during construction and removal of the stream crossing.

Anticipated Life

Generally less than one year.

Flow Capacity

Bank-full flow or peak discharge from a two-year frequency, 24-hour duration storm event without overflow (whichever is less).

Overflow Areas

Protected from erosion from a 10-year frequency, 24-hour duration storm event.

Discharge Velocity at Crossing Outlet

Nonerosive for the stream channel.

Permits

One or more permits may be needed from federal, state, or local permitting agencies. (NOTE: Allow sufficient time for obtaining the appropriate permits.)

Crossing Location

- Locate crossing where it will cause the least amount of disturbance to the channel and surrounding vegetation. (Good locations generally include straight, shallow sections of the channel rather than channel bends and deep pool areas.)
- Install crossing perpendicular to stream flow if feasible.

Road Approaches

- Where feasible, align first 30 to 50 feet of approach road perpendicular to channel flow. (This provides for minimal disturbance to the riparian buffer and eliminates tight turns for construction equipment, thereby reducing the potential for erosion and sediment damage to the stream.)
- Minimize erosion potential by covering with INDOT No. 2 aggregate.
- Place geotextile underlayment under aggregate if soils are soft or if area will be subject to heavy use and heavy loads. (This provides a nonerosive surface, minimizes sediment-laden storm water runoff to the stream, and reduces the potential of vehicular tracking of sediment into the stream.)
- Install water bars (see **Water Bar** on page 89) to divert storm water runoff away from approach ramps where necessary.

Structure

- Stable and nonerosive [clean, non-sediment producing material (i.e., no earth fill in the stream channel)].
- Must not create a flooding or safety hazard.

Materials

- INDOT revetment riprap or larger.
- INDOT CA No. 2 aggregate or larger.
- Geotextile fabric.

Installation/Removal

Stream crossings should be as narrow as practical and streambank vegetation should be preserved to the maximum extent practical.

Installation

1. Where applicable, divert storm water runoff away from roadway approaches and into well vegetated areas, temporary sediment traps (see **Temporary Sediment Trap** on page 183), or an appropriate sediment control measure. Storm water runoff from the roadway should not discharge directly into the stream (see Exhibit 1).

2. Where applicable, divert or isolate channel flow (see **Pump Around/Work Isolation** on page 289) before starting construction of stream crossing.

3. Cut vegetation at locations used for approach road ramps and non-vegetative sediment trapping devices. Where feasible, **do not** grub the stumps or root systems (the root systems help stabilize the streambanks and can help accelerate revegetation of the area). Remove all logs, limbs, and loose debris from the work area and dispose of materials in pre-approved areas located outside the limits of the floodplain.

4. If necessary, install temporary diversions (see **Temporary Diversion** on page 75) and/or water bars (see **Water Bar** on page 89) in road approach sections to divert storm water runoff away from the approach ramps.

5. Excavate and grade the approach ramps, removing all spoil material from floodplain areas.

6. Lay geotextile fabric over the approach ramp foundations (for separation and stabilization), place riprap over the geotextile fabric to the lines and grades shown in the construction plans, and stabilize approach side slopes.

7. Excavate a foundation subgrade across the stream channel for placement of the geotextile fabric, riprap, and aggregate. Allow for placement of the geotextile fabric, riprap, and aggregate without obstructing or restricting the natural flow of the stream.

8. Lay geotextile fabric in the channel bottom (for stabilization).

9. Place riprap over the geotextile fabric to a minimum depth of the specified d_{50} (see Appendix A – Glossary of Terms). Cover the riprap with INDOT CA No. 2, or larger, aggregate (for vehicular driving surface).

Note: **The top of the stone crossing should conform to existing streambed grade with no overfall or obstruction to stream flow.**

Removal

Note: Riprap and aggregate used in ford crossings should only be removed if it impedes stream flow, increases the risk of flooding, or is an obstruction to fish migration.

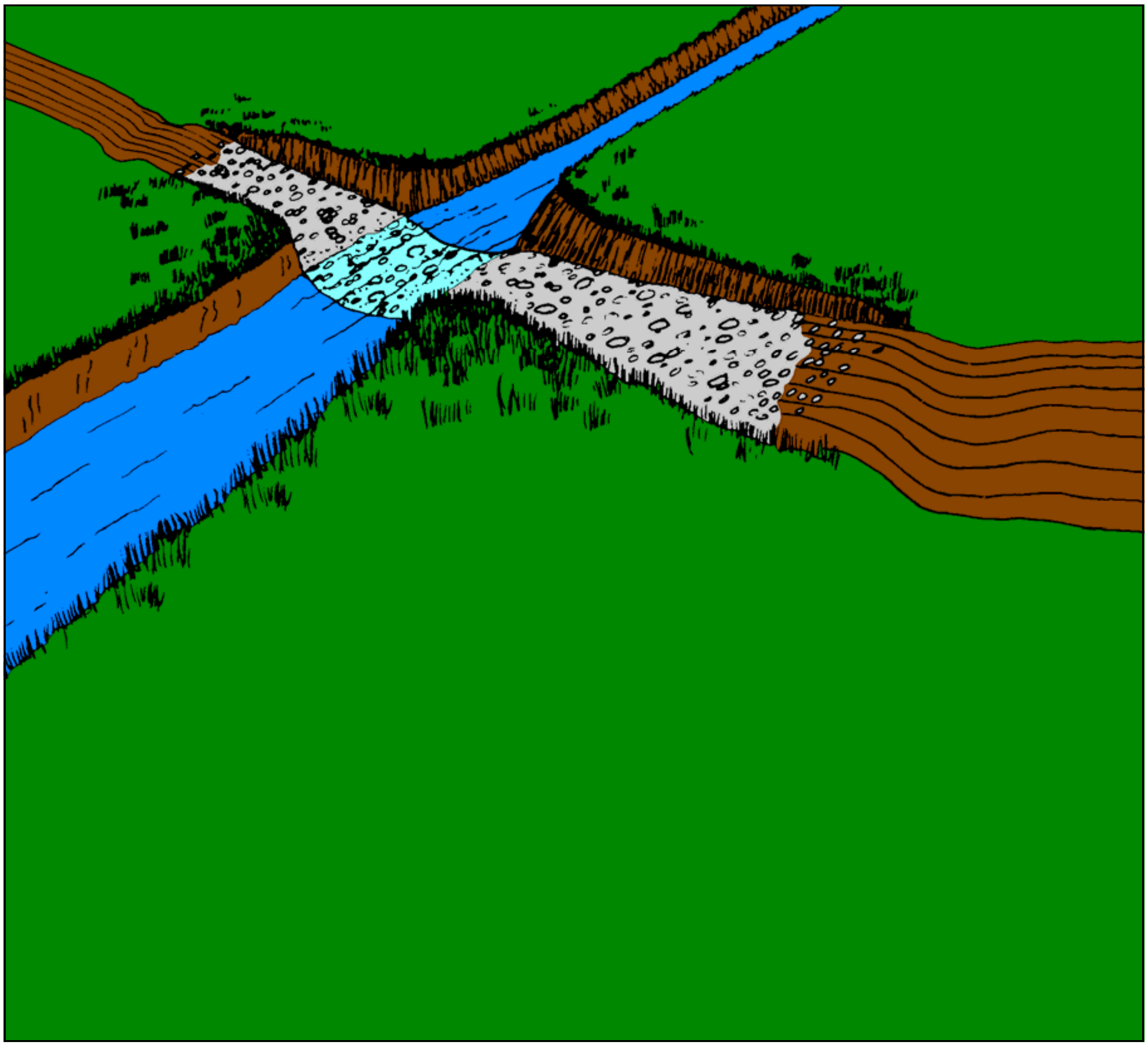
1. Fill road approach ramps, restoring the channel to its original cross section or as specified by the requirements of any applicable permits. Overfill by ten percent to allow for settling.

2. Permanently stabilize all disturbed streambanks, roadway approaches, temporary roadways and other disturbed areas. Stabilize with appropriate permanent vegetative stabilization measures or an appropriate nonerosive armor (see **Surface Stabilization** on page 29).

Maintenance

- Inspect within 24 hours of a rain event and at least once every seven calendar days.
- Check for accumulated debris and obstructions; remove immediately.
- Check for erosion of streambanks and banks of approach ramps; repair immediately.
- Check for sediment deposition. Direct sediment-laden storm water runoff away from stream crossing areas and divert it to appropriate vegetated filter areas or sediment traps.
- Check for damage or displacement of aggregate; repair with clean aggregate.

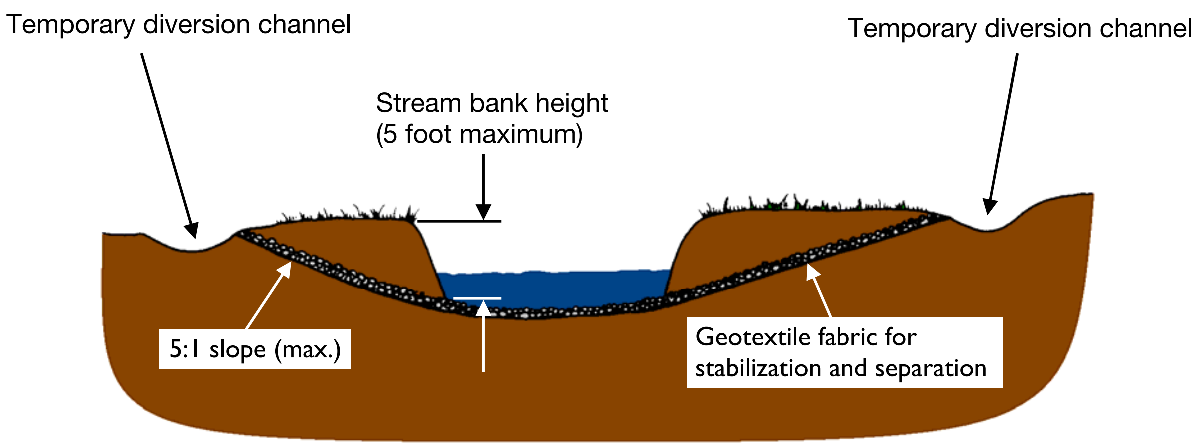
Exhibit 1



Source: Adapted from Virginia Department of Conservation and Recreation, Division of Soil and Water Conservation, 1992

Exhibit 2

Note: This measure requires the designer to provide design specifications and dimensions.



Source: Adapted from Virginia Department of Conservation and Recreation, Division of Soil and Water Conservation, 1992

Cofferdams

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Floating Turbidity Barriers

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Pump Around/Work Isolation

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DEWATERING

Construction projects occasionally require some form of dewatering operation to allow for construction of building foundations, installation of utility lines, or isolation of work areas in and around waterbodies or stream channels. This usually involves the use of a pumping system which siphons water from a pit or trench. When the dewatering operation draws water from the bottom of the pit or trench, it often agitates the soil material on the bottom and results in a slurry which is pumped outside of the pit or trench. This generally results in the discharge of sediment-laden water.

Operators performing dewatering activities should take into consideration the quality of the water that will be discharged. Typically, sediment will be the primary pollutant associated with the discharge water and can be addressed through a variety of sediment control measures. However, it is not uncommon for groundwater or even surface water to contain other pollutants that can potentially be discharged through dewatering. The presence of other pollutants will typically be associated with the former land use of the project site. Several former land uses of concern might be those sites that are considered storm water hotpots. If pollutants of concern other than sediment are associated with the discharge water it may be necessary to provide additional treatment and in some situations obtain additional permits to authorize the discharge.

Measures listed in this section of the manual have been designed specifically to filter or remove soil particles from construction operations requiring the removal of groundwater and/or surface water from excavations. It is extremely important to note that these measures require intensive maintenance and require frequent monitoring, cleanout, repair and/or replacement.

The measures illustrated in this section of the manual are a representation of site management principles and storm water quality measures that can be effective for dewatering operations. The overall objective of this section is to provide options for removal of sediments that may be associated with the dewatering operation. While the measures and principles in this section are representative, the utilization of storm water measures in the Sediment Traps & Basins section on page 181 and the Sediment Barriers & Filters section on page 209 may be utilized and/or modified to specific field conditions to trap or retain sediment. Field modification by contractors of these measures is not uncommon and have proven to be innovative and effective. In addition, there are alternative measures available commercially that may be appropriate for use as part of a dewatering operation.

Designs for dewatering operations can be complex and may require site investigation and, depending on the measure selected, the application of sound engineering principles. Flow rates associated with the pumping operation are critical to the overall design and should be considered when selecting a sediment control measure. Measures should also be selected based on their performance during high flow events associated with rainfall. A professional knowledgeable in these applications and experienced in design should be consulted when selecting measures associated with dewatering.

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Filter Bags

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OTHER RELATED MEASURES

Measures contained in this section are beneficial in managing construction sites and/or controlling erosion and sedimentation. They have been included here because they do not fall cleanly into the other subsections listed in this chapter.

Measures in this section vary in their application. While some measures will not require design, others are more complex and may require detailed site investigations and the application of sound engineering principles. Measures that are more complex will require consultation of a professional knowledgeable in the application of the specific measure and experienced in design.

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Surface Roughening

Surface roughening *is a measure used to create an intricate pattern of ridges and valleys to protect the soil surface from erosive forces, trap eroding soil particles, and enhance vegetative establishment.*

Purpose

- To reduce runoff velocity and increase infiltration.
- To reduce erosion and provide for short-term trapping of sediment.
- To aid in establishment of vegetative cover from seed.

Note: **Although appearing finished, graded areas with smooth hard surfaces are difficult places on which to establish vegetation.**

Specifications

Location

- On slopes that are to be stabilized with vegetation.
- On graded areas that will not be immediately stabilized with vegetation (to reduce storm water runoff velocity until seeding takes place).

Roughening 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. Stair-Step Construction:
   a. Make the vertical cut distance less than the horizontal distance.
   b. Make each vertical cut no more than two feet in soft material or three feet in rocky material.

   c. Slope the horizontal surface of each "step" slightly inward toward the vertical wall (see Surface Roughening – Stair-Step Worksheet).

3. Groove Construction:
   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 parallel to the slope contour.
   b. Make grooves at least three inches deep and no more than 15 inches apart (see Surface Roughening—Grooving Worksheet).

Roughening Slopes (To Be Mowed)

1. Make slopes to be mowed no steeper than 3:1.
2. Use a tiller, disk, harrow, or culti-packer to roughen the slopes, creating shallow grooves no more than ten inches apart, one inch deep, and that run parallel to the slope 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. (This roughening method is generally not as effective as other roughening methods).
2. Operate the tracked machinery up and down the slope so as to leave horizontal depressions in the soil.
   Note: **Do not back-blade during the final grading operation**.

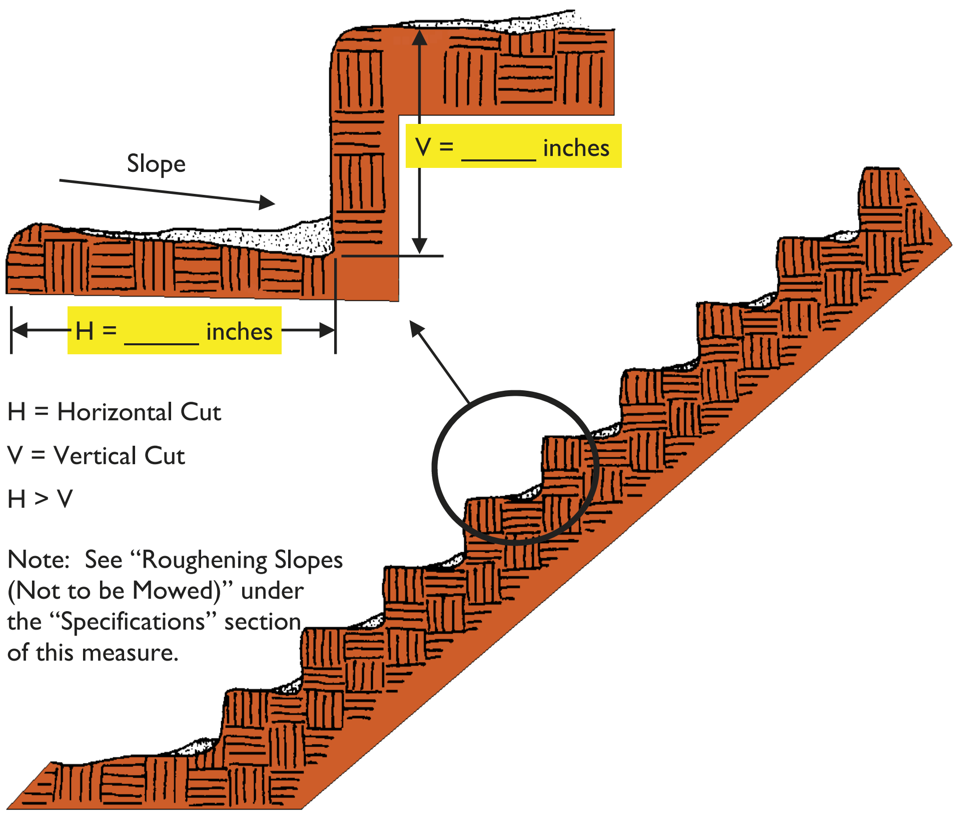
Seeding, Fertilizing, and Mulching Roughened Areas

1. Immediately seed, fertilize, and mulch surface-roughened areas while soil is loose and moist to aid seed germination and vegetative growth (see **Temporary Seeding** on page 31; **Permanent Seeding** on page 35; **Mulching** on page 55 and **Compost Mulching** on page 59).
2. If roughening with tracked machinery, consider seeding, fertilizing, and mulching first, letting the cleats of the tracks incorporate the seed and fertilizer into the soil and anchor the mulch. This is especially well suited for temporary seeding when timeliness is critical and equipment is unavailable for planting operations.

Maintenance

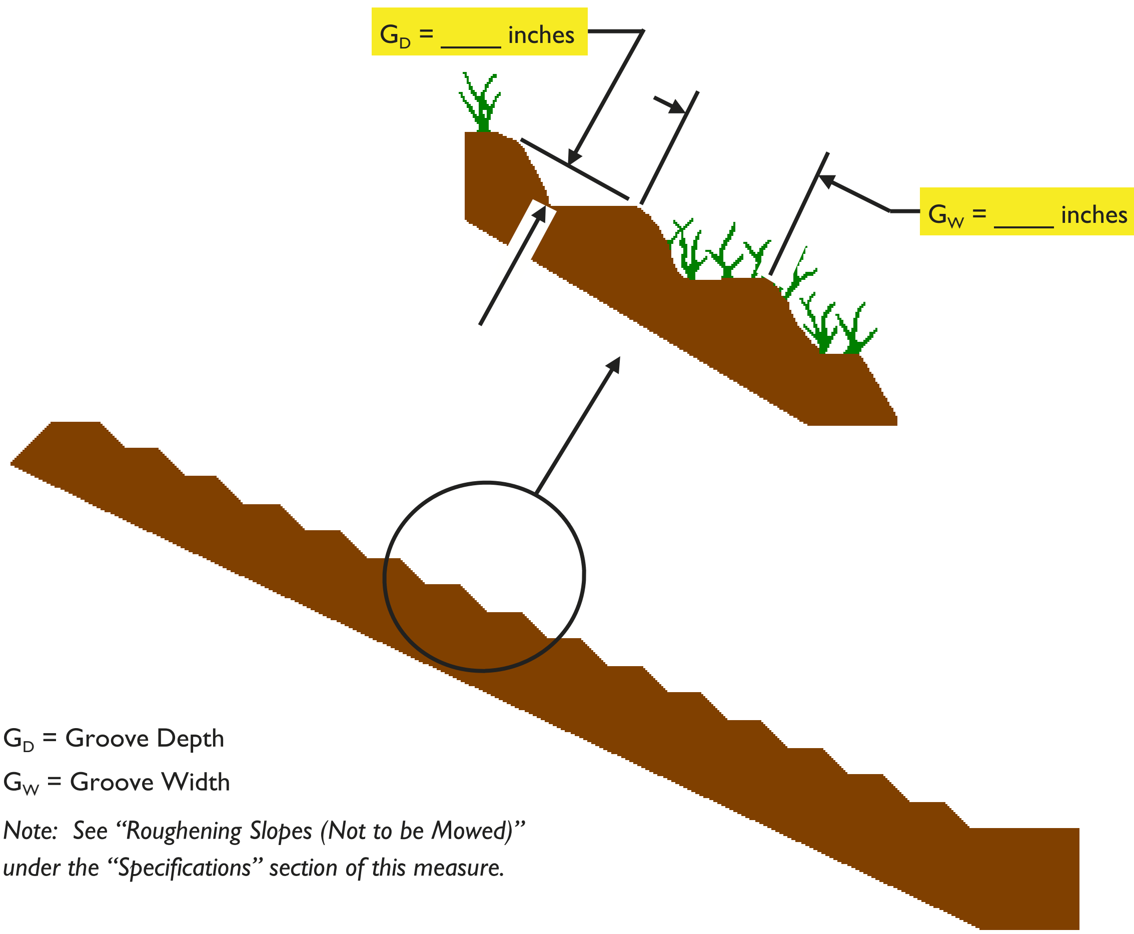
- Inspect daily.
- Periodically check seeded slopes for rills and gullies.
- Fill eroded areas to slightly above the original grade, then reseed, apply mulch and anchor it in place.

Surface Roughening – Stair-Step Worksheet



Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

Surface Roughening – Grooving Worksheet



G_D = Groove Depth

G_W = Groove Width

Note: See "Roughening Slopes (Not to be Mowed)" under the "Specifications" section of this measure.

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

Subsurface Drainage

*Information on **subsurface drainage** is available in Appendix G – U.S. Department of Agriculture, Natural Resources Conservation Service Standards & Specifications for selected storm water quality management measures.*

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Retaining Walls

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8

Post-Construction Storm Water Control Measures

CHAPTER 8

What is Storm Water Runoff?

Storm water runoff is the volume of water generated by a storm that does not infiltrate into the ground or is not retained in storage as surface water. Runoff flows overland during and following a rainfall or snowmelt event, picking up material along the way as it moves downgrade to a river, stream, lake or reservoir. The volume of storm water runoff is related to the amount of impervious surface area in a watershed. Urbanization and the resulting increase in land area devoted to parking lots, rooftops, and additional roads is the primary source of increases in storm water runoff.

Table 1: Percent Impervious Cover Typically Associated With Urban Areas

Land Use	Percent Impervious Cover
Business/Shopping District	95 – 100
High-Density Residential	45 – 60
Medium-Density Residential	35 – 45
Low-Density Residential	20 – 40
Open/Green Areas	0 – 10

Source: Minnesota Pollution Control Agency, Protecting Water Quality in Urban Areas, 1989

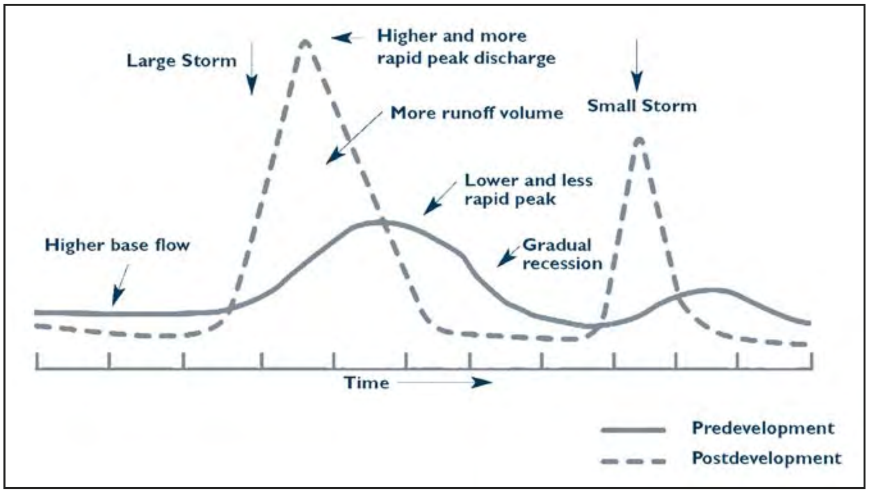
Why Be Concerned with Urban Storm Water Runoff?

Storm water runoff occurs over a very small percentage of the total land area of Indiana, yet it is responsible for a majority of the surface water pollution. As urbanization occurs, the speed with which a drop of water in a remote area of the watershed can make its way to the receiving surface water (i.e., streams or lakes) is increased considerably. Not only is it quicker for water to flow over paved surfaces versus natural soil, but storm sewers further expedite drainage into the nearest lake or river. A drop of water that used to take hours or days to make its way through a watershed to a channel is now there in a matter of minutes or hours.

Surface Flow Changes

The increase in storm water runoff associated with urbanization does not occur without consequences. The increased speed with which the storm water runoff enters the receiving rivers and streams means that channels flood more frequently in response to relatively small storm events. This concept is easily illustrated by a stream hydrograph, a measure of the amount or volume of water passing by a point on a stream over time. As seen on the conceptual hydrographs presented in Figure 1, increased runoff causes the volume of water to increase rapidly, pushing the peak discharge of the stream much higher for the same storm event. The higher the discharge the more power the stream has for erosion, and thus the channel becomes unstable and begins to incise or widen to accommodate the new peak discharge. Unstable channels jeopardize the stability of bridges and other structures located along stream channels.

Figure 1: Preconstruction and post-development flood hydrographs illustrating storm water runoff in response to urbanization



Source: Schueler, 1992; Connecticut Stormwater Quality Manual, 2004; U.S. EPA, 2005, National Management Measures to Control Nonpoint Source Pollution

The same storm event results in two different runoff regimes. Increased development increases the area covered by impermeable surfaces, so the volume of storm water runoff increases and also reaches its peak volume sooner after the initiation of the runoff event.

Pollutants

Storm water runoff picks up a variety of pollutants (see Table 2) that degrade the quality of Indiana's surface waters. Sediment is by far the most visible and common pollutant carried by storm water runoff into rivers and streams. Sediment has drastic effects on aquatic life living in the stream and also causes increased dredging and decreased reservoir capacity over the long term.

The impacts to our waterways from unchecked storm water runoff are substantial. The consequences are not only biological, but economic as well as aesthetic. Populations of fish and other aquatic organisms decrease, recreation money is lost, and property values adjacent to polluted waterways decrease. Often, a blemish of sorts is placed on the reputation of the area where these impacts occur. There are, however, steps that can be taken to mitigate these impacts.

Table 2: Common Pollutants in Storm Water

Storm Water Pollutant	Sources	Impacts
Sediment	Construction sites, disturbed areas, streambank erosion, sand treatment of roadways Degradation/wearing of paved surfaces	• Accumulates in rivers and reservoirs. • Suppresses populations of fish, mussels, and aquatic invertebrates. • Brings in excessive nutrients which are adsorbed by sediment particles.
Nutrients	Fertilized lawns, agricultural applications, leaking sewers and septic tanks	• Causes unchecked growth in aquatic systems followed by deadly anoxic conditions. • Indicated by unusual algal blooms in lakes and rivers.
Bacteria	Animal waste from pets and urban wildlife, leaking sewers, combined sewer overflows	• A major health hazard to humans. • Destroys recreational potential of waterways, causing economic losses. • Increases water treatment costs.
Oil and Grease	Automobiles, industrial areas, illegal dumping	• Limits the interaction of surface water and air by covering a body of water in a film of oil. • Can be deadly to aquatic life and humans in large amounts.
Trace Metals	Automobile wear, exhaust, industrial areas	• Are long lived in the environment. • Often work their way into the food chain and are passed from one organism to another. • Have toxic effects when built up in a system over time.
Road Salt	Roads, parking lots, home applications	• Is lethal to aquatic organisms in high concentrations such as that found in snowmelt.
Chemicals	Pesticide applications, accidental spills, automobiles, illegal dumping	• Lethal to aquatic organisms and often build up in the environment causing problems later on (such as DDT and the demise of eagles).

Source: Adapted from Phillips, 1992

Post-Construction Measures: What Can be Done?

Development is a fact of economic growth in our society and will continue long into the future. We now have the means to develop in ways that are much smarter, minimizing the impacts we have on surface waters both near and downstream of developed and developing areas. There are a variety of design principles, storm water quality measures, and storm water quantity measures that make it possible to minimize environmental impacts. In the specific case of storm water management, mitigating measures have been designed to limit and treat the storm water that is draining into our surface and subsurface waters. This portion of the Indiana Storm Water Quality Manual deals specifically with post construction storm water management measures that can be applied in communities of any age which did not previously have access to these development methods.

Choosing the Right Storm Water Management Measure

Post-construction storm water management measures include active methods that involve constructing a device (such as a detention pond) or changing a particular pattern of activity (such as lawn fertilizing) that can decrease storm water impacts in a given area. Passive methods or source controls are mainly involved with the change in behavior of individuals and community "pre-planning" that involves decisions made prior to and during the construction of new development and redevelopment to limit storm water impact. There are four main storm water management issues that can be addressed with post-construction storm water management measures—sediment, nutrients, toxic chemicals, and storm water runoff.

Sediment

There are two main ways to remove sediment from storm water. One method is to exclude it from storm water drains using some sort of filter or mechanical treatment measure that removes sediment before it can enter the storm water drain. The second method is to slow down or detain the flow of large quantities of storm water so that the sediment settles out before reaching the storm drain. This is accomplished by using some type of storm water detention measure (e.g., dry extended detention basins, wet detention ponds, sediment forebay ponds, etc.). Access to the storm water measure for removal of accumulated sediment is a very important issue to consider when selecting a storm water management measure.

Nutrients

In Indiana, the main nutrients in storm water are nitrogen and phosphorous. Nitrogen is soluble in storm water, whereas phosphorous is usually adsorbed to sediments. In removing sediment, you also remove a tremendous amount of phosphorous from storm water. Soluble nitrogen, on the other hand, is immobilized by plant uptake. Nitrogen is transformed into insoluble forms by plants. Therefore, an effective way to diminish soluble nitrogen levels is to pass the storm water through vegetated wetlands. Keep in mind the nitrogen does not disappear, but rather resides in a different form in the vegetation. Thus, to really remove nitrogen, vegetation may periodically need to be harvested, especially in nutrient-rich environments.

Toxic Chemicals

Toxic chemicals include substances like oil and grease, metals, and various other chemicals that often find their way into storm water. Some hydrophobic materials (oil and grease for example) can be removed by structures placed in a storm drain such as oil-grit separators or hydrodynamic separators. Others, such as metals, can only be contained and cannot necessarily be removed to targeted levels. In-line filtration systems, wetlands, etc. are useful as part of a treatment train for keeping these pollutants from reaching sensitive rivers and lakes through storm water runoff.

Storm Water Runoff

Storm water itself is a concern when present in large quantities. Storm water can be detrimental to the environment due to the sheer volume of water that falls into an area. Storm water detention measures, porous pavement, and subsurface infiltration/detention measures all reduce the volume and speed of storm water entering natural systems. Storm water management measures that promote infiltration and not just detention also promote ground water recharge, an important component often overlooked in storm water management plans.

Maintenance of Storm Water Management Measures

Maintenance is a critical component to the success or failure of post-construction storm water management measures. Storm water management measures must be sited and designed to allow access for inspection, maintenance and cleanout.

Managing Multiple Storm Water Impacts

Most storm water contains some degree of all the detrimental aspects mentioned above, so how can a single storm water management measure be applied to deal with all these factors? The answer is simple; it cannot. Most research indicates that multiple approaches are needed to treat and manage storm water effectively. For instance, a large dry extended detention basin may be constructed to retain and slowly release storm water into the local river to help reduce the size of the discharge spike during flooding. If this dry extended detention basin is also used as a soccer field, we do not want large amounts of sediment to enter the basin. We can construct a sediment forebay pond above the dry extended detention basin to catch the sediment, but not retain much of the water. What if the water contains an unusually high level of nutrients due to fertilizing practices at a local golf course? We can pass the storm water through a constructed wetland area prior to release into the river in order to remove some of those nutrients.

In exactly this way, storm water management measures can be coupled together to perform different functions in a storm water management plan. Often there is considerable overlap between chosen methods, but one method is usually better at treating a certain aspect of storm water than another. Most aspects of storm water management can be addressed with multiple measures. Installation of multiple measures may not always be practical, especially in situations where space is limiting, as in older well-established neighborhoods.

FILTRATION MEASURES

Filtration measures operate on the principal that storm water runoff is intercepted and allowed to pass through a filtering medium such as sand, organic material, or soil for pollutant removal. They are not intended for use as storm water retention measures. Filtration systems are typically used to treat runoff from small residential, commercial, and industrial sites and parking lots. There are two types of filtration systems: (1) surface flow filtration and (2) underground infiltration.

Surface flow filtration systems are typically designed to intercept sheet flow runoff and allow the runoff to pass through the filtering medium. These systems are similar to those used during the construction phase of a project. Surface filtration systems include measures such as compost filters, vegetated swales, and riparian buffer zones. Grass filters and compost mulch berms are two of the more common filtering mediums. In addition to conveying storm water runoff, vegetated swales can provide some filtering of storm water runoff, especially during low flows. Riparian systems are effective filtration measures because part of the riparian zone includes a grass filter as part of the overall system.

Underground filtration systems are used to treat runoff below the surface. These systems are often used in areas with limited space because they can be placed under parking lots and other areas within a project site. Underground filtration systems are typically designed to provide for different levels of pollutant removal. After runoff is filtered it can either be returned to the conveyance system or collected by an underdrain and allowed to percolate into the underlying soil material or infiltration medium. Underground systems include measures such as sand filters and peat filters.

The design of some of the measures identified in this section can be complex and generally require detailed site investigation, including assessment of potential pollutants, and the application of sound engineering principles. A professional knowledgeable of storm water management and water quality principles and experienced in structural design should be consulted when using filtration measures.

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Vegetated Swales

Vegetated swales *are an economical method to reduce pollutants and sediment loads in storm water runoff. Storm water runoff is directed into the swale which conveys the runoff from the site. While moving through the swale, runoff velocity is greatly decreased allowing biofiltration (uptake of nutrients by plants), infiltration (percolation of water through the swale's porous soil substrate), and sedimentation (settling out of larger suspended particles). This measure works best when coupled with other storm water quality measures to reduce the amount of suspended solids that reach the swale.*

Application

Vegetated swales may be used in place of gutters and curbs. Vegetated swales are well suited to highways and residential roads. High density urban areas are not good locations due to space constraints for proper design. This storm water quality measure should not be used without pretreatment/secondary treatment in hotspot areas such as gas stations and manufacturing and industrial facilities because of the concentration of harmful pollutants such as gas, oil, and motor vehicle wastes.

Performance

Proper maintenance is important for effective performance of vegetated swales. Restrictions on the use of vegetated swales include impermeable soils, inadequate space for installation, and runoff containing high levels of pollutants. Efficiency of pollutant removal varies with site characteristics (U.S. Environmental Protection Agency 1999d). Table 1 provides a summary of the average efficiency of vegetated swales in removing pollutants.

Table 1: Average Efficiency of Pollutant Removal by Vegetated Swales

Pollutant	Percent Removed
Suspended Sediments	81
Nitrate	38
Phosphorus	9
Copper	51
Lead	67
Zinc	71

Source: U.S. EPA 1999e

Design Specifications

Given adequate subsurface soil infiltration properties, the design of vegetated swales is centered around two parameters: establishing low flow velocities and maximizing surface area for infiltration. Velocities below 1.5 feet per second promote deposition of suspended sediments and increase hydraulic residence time, maximizing treatment time within the swale. Swales designed with cross sections that maximize ground to water contact have increased infiltration and reduced runoff volume. Parameters affecting channel velocity and infiltration that should be considered in designing a successful vegetated swale are listed below (U.S. EPA 1999d, 2002d).

Siting, design, installation, and maintenance are critical to the performance of swales as a water quality measure. These systems should be designed by a professional proficient in hydrology and storm water design.

Soils

- Soil infiltration rates between 0.5 and 3.0 inches per hour are preferred.
- The clay content of the soil should be less than 20 percent, and the silt/clay content should be less than 40 percent. Both should be in the U.S. Department of Agriculture Natural Resources Conservation Service hydrologic groups A or B.
- Coarse, highly permeable soils should be avoided because they have shorter infiltration times and are less conducive to supporting growth of vegetation.
- Impermeable soils facilitate ponding and should be avoided.
- The bottom of the swale should be at a minimum of two feet above the seasonal water table or bedrock.

- Less desirable soils can be amended to improve infiltration characteristics.

Cross Section Shape

- Parabolic or trapezoidal cross sections maximize infiltration.
- Triangular cross sections should be avoided as they concentrate flow and promote channel erosion.
- Side slopes should be relatively flat (3:1 or flatter).
- Channel bottom width should be between two feet and eight feet (based on cross-sectional area of flow for the channel).

Slopes and Swale Length

- Swale gradients (slopes) of one to two percent are recommended.
- Swale length should be a minimum of 200 feet to encourage deposition.

Vegetative Cover

- Vegetation should be limited to perennial grasses and grass-legume mixes.
- Species of vegetation chosen should have a dense growth habit and be able to tolerate extended periods of flooding.
- Vegetative species can be selected to target different types of pollutants.
- Vegetation height should be maintained at a minimum height of three to four inches.

Design Calculations

- Typical storm intensities should be calculated for each specific site location.
- Swale design should be based on flow rate, not volume. Runoff should pass from the upstream end to the downstream end of the swale in ten minutes.
- Swale should be designed to effectively handle runoff from a one-inch, 24-hour storm event and efficiently pass excess runoff from larger storms (e.g., 10-year storm events).

Note: **Design procedures for this application may be found in "Design of Stormwater Filtering Systems" (Center for Watershed Protection, 1996).**

Other Considerations

In heavy sediment situations, swale performance will benefit from the use of a sediment forebay pond to concentrate sediment at the head of the swale for easy cleanout. During high flow events, velocities within a swale should not exceed the maximum velocity for the type of vegetation cover that is used in order to prevent erosion of the channel vegetation. Check dams may be used to slow velocity and promote infiltration within the channel. Check dams should not induce excessive ponding and precautions should be taken to limit scour directly downstream of the check dam.

Design Modification

The most common approach to storm water treatment is to use a conventional vegetated swale with design modifications to increase the overall efficiency to remove pollutants from storm water runoff. There are also modifications to a conventional swale that may be considered based on site conditions and overall objectives. These two systems are dry swales and wet swales.

Dry swales are similar to a bioretention system. A dry swale requires the native soil to be replaced with an engineered soil/filter medium to promote infiltration and treatment of the storm water runoff. These systems will usually include an under drain system as part of the design. Storm water that is treated in the filtering medium flows into the under drain and is diverted to additional storm water quality measures or to a receiving water (U.S. EPA, National Menu of Best Management Practices, 2002).

Wet swales are similar to a storm water wetland treatment measure, but more linear in design characteristics. This modification of a conventional vegetated swale incorporates a shallow permanent pool and wetland vegetation to treat storm water runoff. Wet swales are not commonly used in residential and commercial settings due to the shallow standing water and the potential for the area to be a breeding ground for mosquitoes (U.S. EPA, National Menu of BMPs, 2002).

Maintenance

Vegetated swales require little maintenance if properly designed (see Table 2). Mowing is the most frequent activity needed in order to maintain channel conveyance.

Costs

Expenses for grass swales vary depending on the size and amount of site preparation needed. Vegetated swales are considered one of the more economically efficient storm water quality measures. Maintenance costs vary, with regular mowing being the standard expense. Poorly designed swales will incur higher maintenance costs over the long term due to erosion and sedimentation maintenance. Using an experienced professional to design the swale may be a higher initial investment, but it can prove to be more cost effective in the long run.

Table 2: Maintenance Schedule for Vegetated Swales

Activity	Schedule
Mowing (minimum height of 3 to 4 inches)	As needed during growing season
Inspect for and correct erosion problems	Twice during first year; annually thereafter
Remove sediment, trash and debris from forebay pond (if installed)	Annually or more frequently if needed
Remove sediment from swale	When sediment reaches 25 percent or less of swale volume
Monitor vegetative growth	Annually inspect to determine if an alternative grass species is more conducive to site conditions

Source: Adapted from Georgia Stormwater Management Manual, 2001; U.S. EPA, 1999e

Additional Information

Internet Keyword Search:
grass waterways, vegetated swales, overflow channels

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Filter Strip (Post Construction)

*Refer to the **vegetative filter strip** measure in Chapter 7, pages 211–214, for more information.*

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Filter Ridge

Source: Rexius, Inc.

Refer to the ***filter berm*** *measure in Chapter 7, pages 229–231, for more information.*

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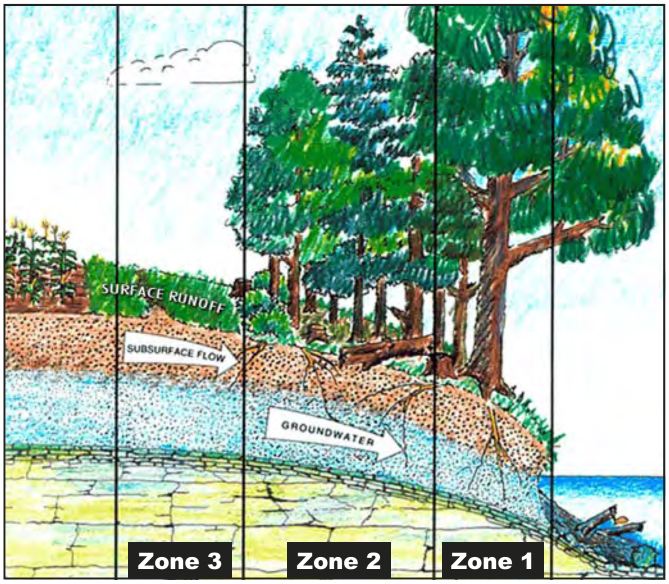
Riparian Buffer Zones

Figure 1: Sketch of a Typical Riparian Buffer



Source: Welsch, 1991

*The term **riparian** applies to any land surrounding or abutting any surface waters. However, it is most commonly associated with the land along a stream or river corridor. Riparian areas provide a unique mix of vegetative components, soil characteristics, and hydrologic attributes. They filter out a significant portion of potentially harmful pollutants associated with sheet flow from storm water runoff before they reach the adjacent waterbody.*

Application

Riparian buffer zones can take many forms, but usually a mixture of native grasses and tree species is recommended. The general layout of constructed riparian buffers follows a three zone system (see Figure 1), each distinguished by their vegetative component, width, and use restrictions. This scheme is highly effective at removing various unwanted pollutants often carried by storm water, although results vary between sites.

Riparian buffers not only act as a filtering mechanism for storm water runoff, but can also create an aesthetically pleasing environment within developments. In addition, having buffers alongside streams or ponds provides immense benefits to aquatic and terrestrial animals by providing habitat and food sources.

Performance

The success of riparian buffer zones depends on a number of conditions including pollutant load, slope of the land, type and density of vegetation, soil structure, drainage patterns, and the magnitude and frequency of storm events. Perhaps the most important thing to remember when constructing a riparian buffer is that overland sheet flow must be maintained in order for the system to operate at peak efficiency. If storm water runoff becomes concentrated, it is rapidly pushed through the riparian zone and discharged into surface waters. The end result is a loss of the riparian buffer zone's filtering ability. In these situations, it may be useful to design retention structures for large storm events that will store excess water and attempt to eliminate concentrated flows during high magnitude events. Table 2 summarizes factors that will enhance or reduce the efficiency of riparian buffers.

Table 1: Pollutant Removal Rates in Riparian Buffer Zones

Study	Vegetation & Buffer Width	Sediment Removed	Nitrogen Removed	Phosphorus Removed
Dillaha et al., 1989	Grass – 15 feet Grass – 30 feet	63% 78%	50% 67%	57% 74%
Lowrance et al., 1984	Forest – Not Applicable	Not Applicable	85%	30–42%
Magette et al., 1987	Grass – 15 feet Grass – 30 feet	72% 86%	17% 51%	41% 53%
Overman and Schanze, 1985	Grass – NA	81%	67%	39%
Schwer and Clausen, 1989	Grass – 85 feet	89%	76%	78%

Source: Summarized from U.S. EPA, 2002c

Table 2: Factors That Enhance or Reduce Performance of Riparian Buffers

Factors That Enhance Performance	Factors That Reduce Performance
• Slopes less than 5%	• Slopes greater than 5%
• Contributing flow lengths <150 feet	• Overland flow paths over 300 feet
• Water table close to surface	• Ground water far below surface
• Check dams/level spreaders	• Contact times less than 5 minutes
• Permeable but not sandy soils	• Compacted soils
• Long growing season	• Short growing season
• Long length of buffer or swale	• Buffers less than 10 feet
• Organic matter, humus, or mulch layer	• Snowmelt conditions, ice cover
• Small runoff events	• Runoff events >2 year event
• Entry runoff velocity less than 1.5 feet/sec	• Entry runoff velocity more than 5 feet/sec
• Swales that are routinely mowed	• Sediment buildup at top of swale
• Poorly drained soils, deep roots	• Trees with shallow root systems
• Dense grass cover, 6 inches tall	• Tall grass, sparse vegetative cover

Source: U.S. EPA 2002c

Design Specifications

Riparian buffer zone design specifications are based upon the three zone system for constructing or maintaining a healthy riparian buffer. Prior to beginning any construction, priority should be given to preserve any existing riparian areas on site. In addition, staking off the riparian buffer and limiting this area from construction traffic is paramount to keeping soil compaction to a minimum.

Table 3: Design Guidelines for Constructing a Three-Zone Riparian Buffer

Zone and Width	Purpose	Vegetation	Management Considerations
Zone 1 25 ft minimum width from top of bank, measured perpendicular to stream.	• Creates a stable ecosystem adjacent to the water's edge. • Reduces runoff nutrient levels. • Provides shade. • Contributes organic matter and large woody debris.	• Mature, native riparian trees, shrubs, forbs, and grasses suited to a wet environment. • Use fast-growing native tree species where banks must be stabilized.	• Exclude heavy equipment. • Harvesting of trees is restricted. • Livestock presence is discouraged except at designated stream crossings. • Avoid concentrated surface runoff through use of flow spreaders.
Zone 2 60 ft minimum width. Note: The minimum combined width of Zones 1 and 2 is the lesser of 100 feet or 30 percent of the floodplain width.	• Provides contact time for filtering process to occur and to sequester nutrients, organic matter, pesticides, sediment, and other pollutants.	• Predominantly native riparian trees, shrubs, forbs, and grasses.	• Concentrated flow must be converted to sheet flow or subsurface flow before entering this zone. • Avoid gully formation by maintaining vegetation and grading.
Zone 3 20 ft minimum width. Note: Ungrazed grassland may serve as Zone 3.	• Provides area to convert concentrated overland flow to uniform sheet flow.	• Dense native perennial grasses and forbs.	• Vegetation should be maintained in vigorous growth. • Weed control may be needed. • Periodic reshaping may be necessary to prevent gully formation. • Harvesting of vegetation for feed is encouraged to remove nutrients.

Source: Adapted from Welsch, 1991

When constructing a riparian buffer where no pre-existing vegetation is present, quick germinating annual grasses (such as annual rye) should be sown throughout all three zones to provide an immediate cover until the perennial species become well established. Additional precautions against erosion, such as applying mulch or a series of silt fences, should be implemented.

As a general guideline, the design specifications may be modified based on community limitations such as property exclusions. In these cases efforts should be made to divert concentrated flow away from these restricted areas and into a section where a healthy riparian buffer has been established. In addition, should any or all of the conditions presented in Table 4 be met, the riparian buffer should be expanded to mitigate for less than ideal conditions.

Table 4: Summary of Poor Site Conditions for Riparian Buffer Zones and Recommended Mitigation Measures

Condition	Evidence*	Expansion
Frequent flooding occurs	Soils in hydrologic groups C and D	Expand width of riparian zone.
Presence of shallow, highly erodible soils	Soil capability classes IIIe/s and IVe/s	Increase combined width of Zones 1 and 2 to 100 feet.
Presence of shallow, highly erodible soils	Soil capability class VIe/s, VIIe/s, and VII	Increase combined width of Zones 1 and 2 to 150 feet.
Steep slopes	Steep slopes	Increase width of riparian zone to 1/3 of the distance from stream to top of slope.

Source: Adapted from Welsch, 1991

* Soil classes and soil capability classes can be found in Natural Resources Conservation Service county soil surveys.

Costs

The cost of implementing riparian buffer zones into a development can often be offset by an increase in property values or the production of products (such as hay or timber) from the managed riparian zone. A number of studies have documented the relationship between increased aesthetic values of property and the increase in property values. In addition, the start-up costs for managing a riparian buffer are mainly in the materials so that once this initial expense is incurred, the zone will remain largely self sufficient, with limited expenses for annual or biannual maintenance.

Costs for materials, such as seed and tree stock, will vary among regions. Consulting a local cooperative extension service office, local soil and water conservation district office, or U.S. Department of Agriculture Natural Resources Conservation Service office can provide a solid starting point for gauging which types of vegetation are best to plant given your region and where economical sources of materials can be found.

Additional Information

Internet Keyword Search:
riparian buffers, buffer strips, filter strips, riparian zones

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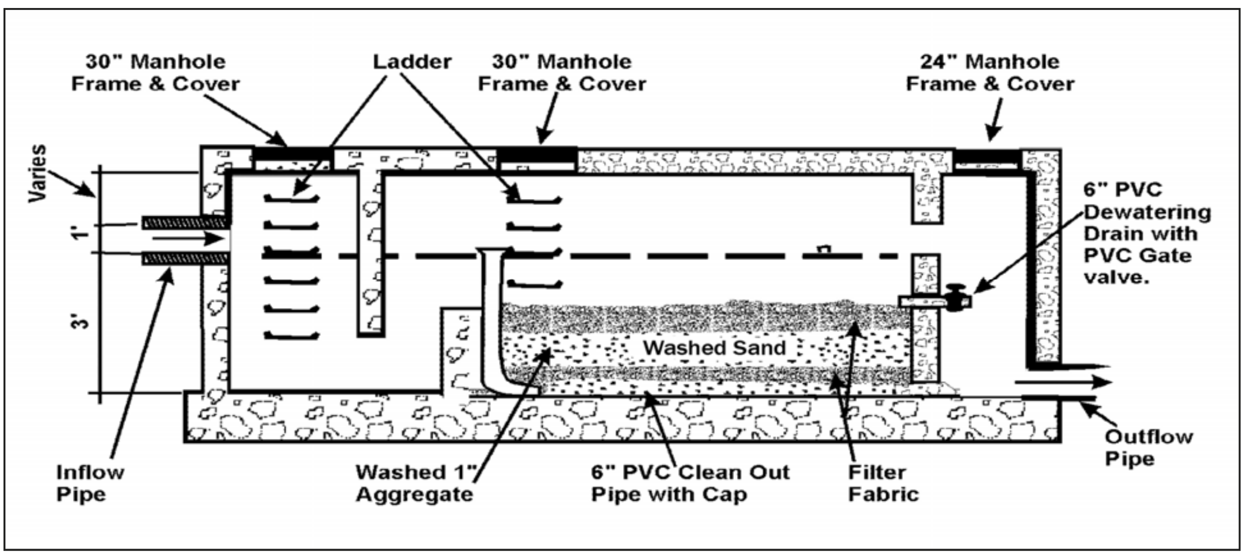
Sand Filters

Sand filters *are structural storm water quality measures comprised of two or three chambers through which storm water runoff passes. Sand filters can be effective in removing sediments, coliform bacteria, and lowering biochemical oxygen demand by removing organic matter.*

There are three main types of sand filters in use. They vary in design, chamber placement, and drainage area treated. The Washington D.C. filter (see Figure 1) is a three-chamber system. The first chamber is used to remove surface pollutants and sediments.

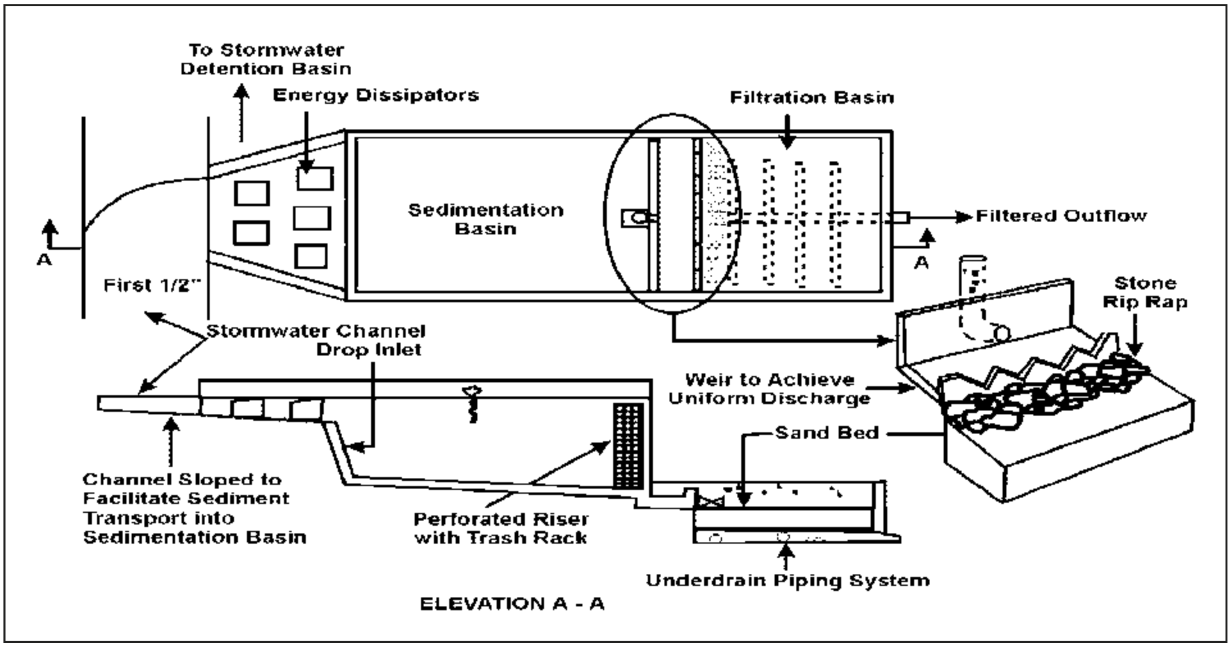
The second chamber filters pollutants by allowing flow through a sand bed. The third chamber is for collection of filtered water, at which point the water proceeds to a storm drainage system or directly to surface water. The Austin (see Figure 2) and Delaware (see Figure 3) filters are two-chamber systems. These systems are similar to the first two chambers of the Washington D.C. filter. The need for the third chamber is eliminated by the placement of a drainage medium in the bottom of the second chamber.

Figure 1: Diagram of a Washington D.C. Sand Filter Design



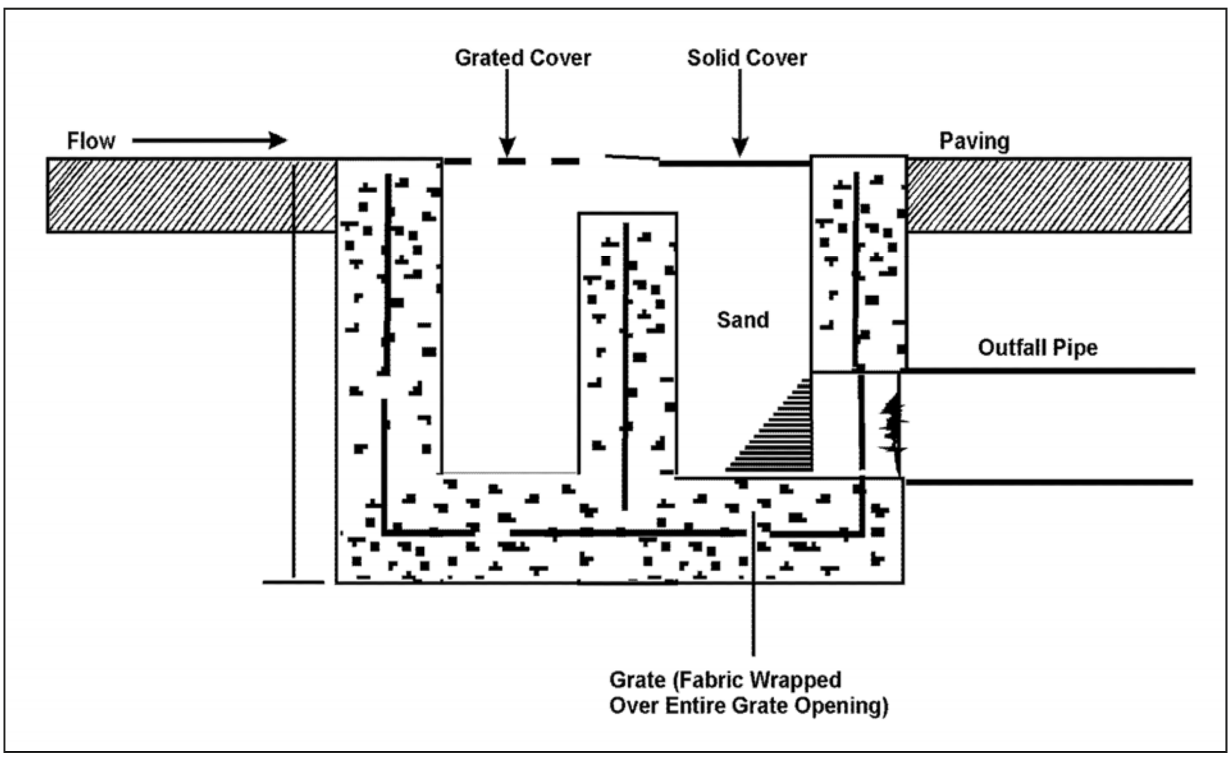
Source: Truong, H. V., 1989

Figure 2: Diagram of an Austin Sand Filter Design



Source: Schueler, 1992

Figure 3: Diagram of a Delaware Sand Filter Design



Source: Shaver, 1991

Application

The suitability of these systems is highly dependent on the characteristics of the contributing drainage area. These systems are well suited to high traffic areas, parking lots, loading docks, service stations, garages, airport runways/taxiways, and storage yards. The Delaware and Washington D.C. sand filter systems are usually installed in highly urbanized areas with impervious surfaces and where land availability to install other above ground measures is limited. The Austin sand filter system is an above ground system and is suited to larger drainage areas. This system is typically installed to treat drainage areas that have a combination of both impervious and pervious surfaces. Typical applications for the Austin sand filter include transportation facilities, large parking areas, and commercial development areas.

Sand filters are designed for treatment of pollutants associated with storm water runoff. Sand filters are an option over infiltration trenches when pollutants such as biochemical oxygen demand, suspended solids, and fecal coliform are a concern and there is a threat of ground water contamination. Site conditions that pose a threat of ground water contamination include soils with high permeability rates, fractured bedrock near the surface, or ground water tables above the design depths of an infiltration trench. Sand filters are closed systems with impermeable chambers that treat the storm water runoff before discharging to a storm water drainage system or receiving water.

Table 1 provides estimates of average pollutant removal for a variety of sand filter systems. The table does not indicate removal rates for nitrate. Other pollutants that may be associated with various land uses were not monitored as part of this data. Monitoring of sand filter systems continues to be performed to evaluate their effectiveness.

These systems, although diverse, have disadvantages. Careful evaluation of these systems in comparison to other storm water quality measures or treatment systems (treatment train) should always be considered before selecting a final treatment option. Table 2 lists several advantages and disadvantages for these systems.

Table 1: Pollutant Removal Rates in Sand Filters

Pollutant	Percent Removed
Fecal Coliform	76
Biochemical Oxygen Demand	70
Suspended Sediments	70
Nitrogen	21
Phosphorous	33
Iron	45
Lead	45
Zinc	45

Source: Galli, 1990

Table 2: Advantages and Disadvantages of Sand Filters

Advantages	Disadvantages
Filter media being removed permanently removes trapped pollutants	Limited use due to small drainage area and inapplicability to nutrient and metal removal
Filter media is generally nontoxic and can be disposed of in landfill	Requires routine maintenance to remove sediment clogged in filter
Reduces potential for groundwater contamination	Does not control storm water flow so does not prevent downstream bank erosion
Requires less land than ponds or wetlands	May not be as useful in cold climate

Source: U.S. EPA, 1999d

Table 3: Types of Sand Filters and General Information

Filter System	Drainage Area	Best Application	Location of System
Austin	Large impervious and pervious systems ≤ 50 acres	Parking areas, commercial lots	At surface
Delaware	Mostly impervious ≤ 5 acres	Runoff from high traffic areas	Below ground
Washington D.C.	Totally impervious ≤ 1 acre	Runoff from high traffic areas	Below ground

Source: U.S. EPA 1999d

Design Specifications

Siting, design, installation, and maintenance of sand filters are critical if they are to function properly and efficiently. Therefore sand filters should be designed by a professional proficient in hydrology and storm water design.

Following is a list of specifications for the three types of sand filters that were pictured earlier in this section. This information was assembled from information contained in the U.S. Environmental Protection Agency, *Storm Water Technology Fact Sheet, Sand Filters* (EPA 832-F-99-007, September 1999). Additional information for the Delaware Sand Filter was obtained from the Delaware Department of Natural Resources and Environmental Control (*Sand Filter Design for Water Quality Treatment*, Shaver, E., 1991, Update 1998). In addition to these references, the Center for Watershed Protection publication titled *Design of Stormwater Filtering Systems* (1996, December) provides an in-depth discussion of design parameters and procedures to aid in the design of sand filters.

Austin Sand Filter

- Maximum drainage area ≤ 50 acres.
- Sedimentation chamber designed to either accommodate full runoff flow or only partial flow (e.g., first 0.5 inch).
- Partial system can hold 20 percent of first flush in sedimentation chamber whereas full system can hold all of first flush in chamber.
- In-flow is passed through a trash filter and discharged into the filtration chamber which contains an 18-inch thick bed of 0.02 to 0.04 inch diameter sand particles.
- Flow percolates through the sand bed and discharges into a four to six-inch perforated drain pipe with 0.4 inch perforations. Filter fabric is placed over the perforated drain pipe to prevent soil particles from clogging the pipe.
- Water collected in the drain pipe is discharged back into the primary drainage system.

Washington D.C. Sand Filter

- Maximum drainage area ≤ 1 acre.
- Often constructed online but can be used offline. Sedimentation chamber accommodates first 0.5 inch of storm water runoff.
- Storm water runoff collected in the first chamber is passed through a submerged weir and discharged into a filtration chamber where a 3.3 foot layer of sand and gravel is used to filter the runoff.
- Water filtered through the sand and gravel filter medium is collected in perforated drain tile wrapped with filter cloth. This water is then discharged into a third chamber which is connected to the main storm water drainage system.
- An overflow weir is located between the second and third chambers to allow for bypass of larger storm events. In the offline system this is not necessary.

Delaware Filter

- Maximum drainage area ≤ 5 acres.
- Very similar to the Washington D.C. sand filter except that it only has a sedimentation chamber and a filtration chamber.

- Storm water runoff passes through a grated cover to a sedimentation chamber where it passes over a weir and discharges into an 18-inch thick sand bed. If gravel is used in place of sand, the design must be modified.
- Volume of sedimentation chamber is sized, at least, for 540 ft^3 of storage per acre of drainage area.
- Volume of filtration chamber equals volume of sedimentation chamber.
- Surface area of each chamber is 360 ft^2 per acre of drainage area.
- Shallow depth of the structure (30 inches) is convenient for construction and maintenance.

For all design models, the life of the sand filter can be prolonged by stabilizing the drainage area so sediment load is reduced, providing adequate storm detention times to aid infiltration, and scheduling regular inspections and frequent maintenance.

Maintenance

All sand filter systems should provide easy access for inspection and maintenance activities that will be performed to maintain the system. These systems should be inspected after every significant storm event (.5 inches or more). Trash and other debris that accumulate in the chamber should be removed a minimum of every six months or as needed if the drainage area contributes significantly to this problem.

Filters will typically begin to experience clogging every three to five years (Northern Virginia Regional Commission, 1992; U.S. EPA, 1999d). The filter media (sand) will need to be removed periodically. According to U.S. EPA the contaminated media removed from these systems does not appear to be toxic and is environmentally safe to be disposed of in a permitted landfill facility. However, as a precaution periodic testing of the material removed is recommended.

These systems will require regular inspection and maintenance. The operation life of the sand filter can be increased by:

- Inspecting the sand filter frequently to ensure operation.
- Stabilizing the contributing drainage area to reduce sediment loading.
- Removing leaves, debris, and grass clippings within the drainage area that is directed to the filter.
- Maintaining the capacity of the sand filter to enhance sedimentation and filtration.

Costs

Installation costs vary based on the type of sand filter structure used. Annual maintenance costs should average about five percent (Schueler, 1997; U.S. EPA, 1999d) of the original construction costs.

Additional Information

Internet Keyword Search:
sand filters, peat filters

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Peat Filters

To be released at a later time

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INFILTRATION MEASURES

Infiltration measures are storm water management measures designed to collect storm water runoff and provide a suitable medium that allows the runoff to infiltrate into the ground. Storm water infiltration measures reduce storm water volumes and the associated suspended solids and pollutants attached to suspended soil particles. Storm water infiltration measures also provide ground water recharge. These systems are not effective in removal of water soluble or dissolved pollutants.

Infiltration systems work on the principal that stored storm water runoff is slowly released to ground water. The permeability of the underlying soil material is critical in the implementation of this measure. Infiltration measures should be carefully sited and designed to minimize the risk of ground water contamination.

Storm water infiltration measures are best suited for treating storm water runoff generated from small residential areas and commercial developments. Infiltration systems should not be used in areas where the land use of the contributing drainage area is associated with chemical storage, high levels of pesticides, the washing and maintenance of vehicles or equipment, or where wastes are handled.

Infiltration measures are prone to sealing or plugging. Therefore, storm water runoff should be pretreated to remove solids, oil, grease, and floatables before allowing the runoff to discharge into the infiltration measure. Infiltration measures should not be used in areas with high sediment loads or during construction, especially in situations where sediment-laden runoff from disturbed areas will be directed into the system.

The design of infiltration measures can be complex and generally requires detailed site investigation, including an assessment of potential pollutants and the application of sound engineering principles. A professional knowledgeable of storm water management and water quality principles and experienced in design should be consulted when using infiltration measures.

Infiltration measures include but are not limited to porous pavement, porous paver systems, infiltration trenches, and infiltration ponds.

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Pervious Concrete Systems

Pervious concrete systems *are special types of pavement systems that allow rain and snowmelt to infiltrate through the pavement material and discharge into an underlying stone reservoir that temporarily stores the storm water runoff. The stored runoff is then allowed to infiltrate into the underlying soil material, discharge into an auxiliary drainage system, or discharge into a secondary storm water quality treatment device. Pervious concrete is a structural pavement that is manufactured without "fine" materials. The reduction in amount of fine materials allows for larger interconnected voids which in turn allows for storm water infiltration.*

Pervious concrete systems have an advantage over conventional pavement systems because they minimize the disruption of an area's hydrology, facilitate ground water recharge, and can provide water quality benefits. This is especially important in highly developed areas where the majority of the land surface is covered with concrete or asphalt pavement.

Application

There are several factors that dictate where pervious concrete systems can be used. These include but are not limited to soil type and seasonal high water table. These factors are directly related to site selection and design requirements that are discussed later in this section. One of the primary questions associated with pervious concrete is its application in colder climates. Issues include winter maintenance activities as well as the potential for system failure due to frost heave. Maintenance is critical to the success or failure of these systems and is addressed later in the section. The potential for frost heave can be addressed through design modification that provides for an adequate base layer that will reduce this risk. Proper installation is also critical and should be performed by trained individuals.

The following land uses are commonly associated with pervious concrete systems.

Pedestrian Areas

Pervious concrete systems are ideal for sidewalks and other pedestrian walkways, rollerblade and bike pathways, and areas such as patios and common areas around residential buildings.

Transportation Areas

Pervious concrete systems are well suited for the construction of lightly used access roads, overflow parking areas, and low-volume traffic areas around office buildings, recreational areas, and shopping centers. Other areas where pervious concrete systems may be used include emergency stopping areas, traffic islands, vehicle crossovers on divided highways, and shoulders along roadways, airport taxiways, and airport runways. Pervious concrete systems have typically been restricted to the land uses listed above, however pervious concrete systems may accommodate higher volume traffic and heavier truck traffic use. To achieve these objectives, special mix designs and structural design modifications and placement techniques will be required.

Pervious concrete systems are poorly suited for use in areas where it is necessary to apply sand or other deicing agents to the pavement surface. Sand has a tendency to clog the surface of the pavement material, whereas other deicing agents may migrate into the ground water.

Ultra Urban Areas

Pervious concrete systems can be a good option in densely developed urban areas which typically have little pervious surface area. Pervious concrete systems in this kind of setting allow infiltration of storm water which in a conventional setting would be lost because of lack of permeable surface areas and efficient storm water drainage systems.

Storm Water Hotspots

Infiltration of storm water into the underlying soil material is not recommended to treat runoff from designated storm water hotspots due to the potential for ground water contamination. Pervious concrete systems should not be used for industrial and manufacturing sites where there is a high concentration of soluble pollutants, pesticides, fertilizers, and heavy metals. Storm water hotspots include areas such as gas/fueling stations, truck stops, vehicle service and maintenance areas, vehicle and equipment washing/steam cleaning facilities, auto recycling facilities, loading and unloading facilities, commercial storage areas, outdoor container storage areas, public works storage areas, commercial nurseries, marinas, hazardous material generators, and industrial rooftops because these areas are frequently subject to the high risk of ground water contamination.

Advantages

- Allows rain and snowmelt to pass through the pavement material.
- Provides water quality benefits by filtering pollutants (e.g., petroleum hydrocarbons, metals, organic matter, and nonpoint source pollutants such as phosphorous attached to fine soil particles) from storm water runoff via infiltration into the underlying soil substrate and through microbial action.
- Reduces the volume of storm water runoff and associated erosion potential (U.S. Environmental Protection Agency studies have shown that pervious concrete systems can reduce storm water runoff by as much as 80 percent).
- Attenuates peak discharge flows and reduces the amount of storm water entering storm drain systems.
- Provides some natural filtration capacity while maintaining the structural and functional features of the conventional pavement material it replaces.
- Stone reservoir can be lined with an impermeable liner, allowing storm water to be reused, stored, or treated through utilization of a secondary storm water treatment measure.
- Minimizes the disruption of the hydrology of an area by providing a reservoir and percolation field for surface water to re-enter ground aquifers, recharges low flow in streams during dry periods, and reduces downstream flooding.
- Minimizes the amount of land consumption by reducing the need for traditional storm water management structures, thereby saving open space for alternative uses.
- Minimizes construction and maintenance costs of street curbs and gutters, storm sewer systems typically required to carry storm water to an outfall, and other associated storm water management measures such as retention/detention ponds.
- Improves roadway safety by reducing noise, improving visibility in wet weather conditions, and reducing risk of skidding/hydroplaning.
- Allows for pavement to extend under the dripline of trees.
- Cooler than black asphalt because of higher reflectivity and lower solar heat-gain from absorption and evapotranspiration.
- Cooler pavement temperatures allow for infiltration of cooler storm water into ground water.

Disadvantages

- Pavement engineers and contractors may not possess the expertise and experience to apply this technology (generally requires special planning and expertise to install).
- Poorly suited for use in naturally occurring seasonal high water table soils.
- Poorly suited for use in wellhead protection areas.
- The pavement surface, if improperly installed and maintained, has a tendency to become clogged with particulate matter and debris.
- Not suitable for use in areas where materials applied to the roadway can clog or fill voids in the pervious concrete (e.g., chip and seal operations or application of sand to ice covered roadways).
- Poses a risk to ground water contamination. For example, pollutants such as nitrates and chlorides that are not easily trapped, absorbed, or reduced may continue to move through the soil profile and into ground water (dependant on soil conditions and aquifer susceptibility).
- Potential risk for vehicle fuels, oils, greases, and other substances to leak onto the pavement and leach into ground water.
- May cause frost heave of pavement if system is improperly designed, installed, or maintained.
- Pervious concrete systems typically have higher maintenance requirements than conventional pavement systems.
- Local building codes sometimes restrict the use of pervious concrete systems without special approval or variances.

Performance

The initial performance of porous/pervious pavement systems has been very good. However, according to the U.S. Environmental Protection Agency the failure rate over time has been high. Failure has been attributed to poor design, inadequate construction techniques, poor siting, and poor maintenance. When these issues are addressed, it is anticipated that these systems can have a service life of 20 years or more.

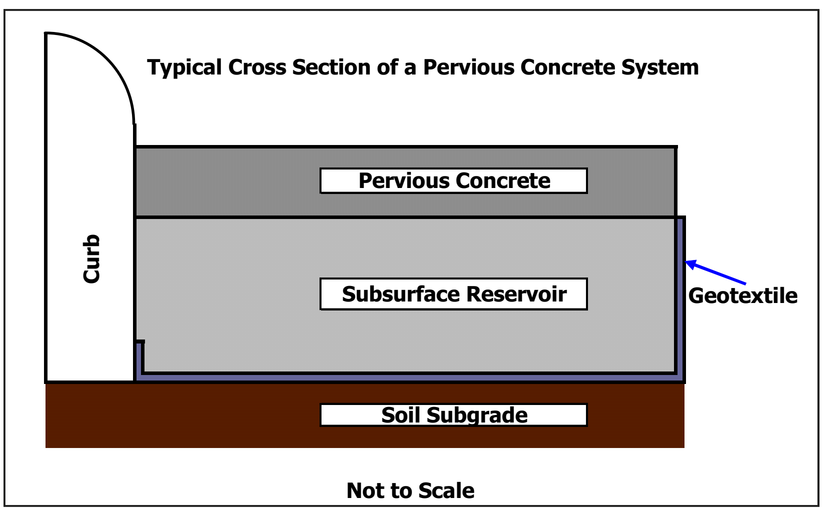
Properly designed, installed, and maintained pervious concrete systems can be cost effective and provide a storm water management system that promotes infiltration and the removal of pollutants from storm water runoff flowing through the system. Pollutant removal mechanisms associated with these systems include absorption, straining, and microbiological decomposition. Pollutant removal effectiveness will vary depending on system design, soil substrate characteristics, and proper maintenance of the system. Sampling data for these systems, although limited, indicate a relatively high removal rate for total suspended solids, metals, and oil and grease. These systems can be installed as part of a treatment train to increase the overall efficiency of removal for targeted pollutants.

Design Specifications

Siting, design, installation, and maintenance of pervious concrete systems are critical if they are to function properly and efficiently. Therefore, pervious concrete systems, and especially the storm water component, should be designed by a professional proficient in hydrology and storm water design. Installation should be performed by trained individuals (the concrete industry offers a certification program for installers). Design and installation should be in conformance with concrete industry standards and specifications.

Information in this section was assembled from a variety of sources including the U.S. Environmental Protection Agency's storm water technical fact sheet entitled *Porous Pavement* (1999h); the U.S. EPA's post-construction storm water management in new development and redevelopment fact sheet entitled *Porous Pavement* (2002k); the Indiana Ready Mix Concrete Association; and the Georgia Stormwater Management Manual (2001).

Pervious concrete systems should include evaluating and incorporating basic features into the design including but not limited to pretreatment, treatment, conveyance, and landscaping.



Pretreatment

Pretreatment should be considered, and is especially recommended, where oil and grease or other potential ground water contaminants are expected. In most pervious concrete system designs the pervious concrete itself is considered to act as the first level of storm water runoff pretreatment. System designers should take into account pollutants that are associated with the land use and apply appropriate pretreatment measures to target specific pollutants.

Adjacent areas that drain to a pervious concrete system should be stabilized and/or designed so that runoff from an adjacent area will not deposit sediment onto the pervious concrete surface. Otherwise, frequent maintenance of the pavement surface is critical to prevent clogging.

Treatment

A stone reservoir should be incorporated into systems where soil conditions are not favorable to promote infiltration. The reservoir, which lies immediately beneath the pavement, should be designed and sized to attenuate and treat a small storm water runoff event (typically 0.5 inch to 1.5 inches). Storage capacity must be designed around the amount of air/pore space in the reservoir since this is the only area where water can be stored.

Conveyance

Pervious concrete systems need some method of conveying storm water runoff through the system. Pores in the pervious concrete allow storm water to infiltrate into the underlying stone reservoir. Water stored in the stone reservoir is then allowed to either infiltrate into the underlying soil substrate or held in an underground impermeable closed system that discharges to a secondary storm water management/treatment measure via subsurface drainage pipes.

Pervious concrete systems should be designed with some method to convey large storm events to the underlying stone reservoir. Setting storm drain inlets at strategic locations within the system design will allow larger storm water flows to enter the stone reservoir in the event that the infiltration rate of the pavement is insufficient to handle the storm event or the pavement surface becomes clogged.

Landscaping

Preventing sediment loads from clogging the pervious concrete surface is critical if the system is to function properly. Therefore, it is important to develop and implement a landscaping plan that will ensure that the contributing drainage area is stabilized. This is especially true during active construction, but is also applicable for post-construction activities.

Design of pervious concrete systems also requires evaluation and incorporation of several key elements such as, but not limited to, soil type, infiltration rate, depth to a limiting layer (e.g., bedrock, a seasonal high water table, glacial till), slope length and gradient, construction materials, and installation methods. Following are several key design specifications that should be considered and evaluated when siting, designing, and installing pervious concrete systems.

Siting

- Select infiltration opportunities within the immediate development area.
- Avoid conveying storm water long distances.
- Consider past use of the site and appropriateness of infiltration design with pervious concrete.
- Consider the source of the storm water runoff to be treated.
- Minimum setback of 100 feet from wells used to supply drinking water. State rules or local ordinances may require distances greater than 100 feet.
- Minimum setback of 100 feet up-gradient of building foundations. Local building codes may dictate setback requirements.
- Minimum setback of 10 feet down-gradient of building foundations. Local building codes may dictate setback requirements.
- Poorly suited for use in naturally occurring seasonal high water table soils.
- Poorly suited for use in wellhead protection areas.
- These systems are not suitable in areas with karst geology without adequate geotechnical assessment by qualified individuals. System placement and design may also be subject to local requirements or ordinances.
- Soil Substrate
  - Perform site tests to determine depth to seasonal high water table, depth to bedrock, and soil limitations, including infiltration capabilities.
  - Soils should be homogeneous and should not have any compacted layers.
  - For optimal performance, locate systems on deep, well-drained, permeable soils. Soil should have field-verified permeability rates between one-half and three inches per hour or silt/clay contents of less than 40 percent and be in U.S. Department of Agriculture Natural Resources Conservation Service hydrologic groups A or B. Permeability rates of less than one-half inch per hour and soils with higher clay content can be accommodated through special design.
- The ideal application of pervious concrete systems is typically on slopes of two percent to five percent. Pervious concrete can be installed on steeper slopes with appropriate design modification.

General Design Considerations

- Contributing impervious surface to pervious concrete system ratio should be no more than 3:1.
- Design to minimize amount of storm water runoff pervious concrete system receives from adjacent areas. If necessary divert runoff from adjacent areas into the stone reservoir before it reaches the pervious pavement surface. This can be done by incorporating an unpaved stone edge at the perimeter of the pavement or installing catch basins designed to discharge into the stone reservoir. (Note: The unpaved stone perimeter and/or catch basins can also act as an emergency entrance/spillway that will allow storm water runoff to enter the stone reservoir in the event that the pervious concrete surface becomes paved over, clogged, or forgotten.)
- Design the system to contain spills.
- The ideal application of pervious concrete systems is typically on slopes of two percent to five percent. Steeper slopes may be accommodated through design modification to reduce or eliminate erosion below the pervious system, using perpendicular trenches, terracing, stone, and filter fabric.
- Avoid excessive cut and fill earthwork by designing the system to fit the contours of the site.
- Use sufficient pavement thickness to protect the subgrade from being overstressed.
- Do not infiltrate stored storm water runoff into compacted fill because the permeability will often be too slow.
- Place observation wells downstream of the pervious concrete system.

Geotextile Fabric Liner

- Use nonwoven geotextile fabric of at least four ounce weight to allow water to drain into the soil while preventing soil particles from moving into the stone bed.
- Placed on uncompacted natural soil.
- Placed flush with soil surface (bottom and sides) of excavated stone reservoir and overlapped a minimum of 12 inches between adjoining rolls.

Stone Reservoir

- Size and depth of reservoir is determined by soil infiltration rate, total impervious surface area (i.e., contiguous impervious roadways and streets, rooftops, etc.) drained into the reservoir, design storm event, and frost line depth.

- Depth of reservoir is based on design storage capacity and land use. Typically, the minimum reservoir depth is six inches.
- Twelve-hour minimum and 72-hour maximum draw-down time with a recommended draw-down time of 24 to 48 hours. (Note: Microbiological decomposition can be impeded if soils are unable to dry out and anaerobic conditions are allowed to develop between storm events.)
- Design storage capacity should not include those areas above the pavement. Designers may also choose to exclude the pervious concrete as part of the design storage capacity based on concrete industry specifications and regional climatic issues and the potential for frost heave.
- It is also important to design pervious concrete systems with a mechanism to discharge water from the stone reservoir in the event that its design storage capacity is exceeded. An exfiltration system should be incorporated into a system that is installed in soils with a permeability rate of less than one-half inch per hour or with a high clay content. The stone reservoir component of pervious concrete systems must be designed with an exfiltration system that allows large storm events to exit the reservoir. Drainage of excess water in the stone reservoir is typically accomplished in one of three ways: full exfiltration, partial exfiltration, or water quality exfiltration.

  - Full Exfiltration System – The stone reservoir is an enclosed system (i.e., no pipe outlets) that only allows runoff to exit the system via infiltration into the soil substrate. The reservoir storage capacity must be large enough to accommodate the entire runoff volume from the design storm. An aboveground emergency overflow channel such as a swale or raised curb is used to collect excess runoff from storm events greater than the design storm and divert it to an auxiliary storm water treatment device.
  - Partial Exfiltration System – The stone reservoir is connected to an underground drainage system that includes regularly spaced, perforated pipes located in shallow depressions. The pipes collect the stored runoff and direct it to an infiltration basin or a central outlet. Size and spacing of the under-drain system should allow for passage of the design storm event.
  - Water Quality Exfiltration System – The stone reservoir is designed to store the first flush (i.e., volume of runoff produced by a one-inch storm event or the design storm event) of runoff volume from the design storm event. Runoff volumes in excess of the first flush are not treated by the pervious concrete system, but are conveyed to an auxiliary or secondary storm water treatment measure.

- The bottom of the reservoir should be a minimum of three feet above any limiting layer (e.g., seasonal high water table, glacial till, bedrock).
- The base of the reservoir should be extended below the frost line to reduce the risk of frost heave.

- The bottom of the reservoir should be level to allow even distribution and infiltration of storm water and prevent the development of preferential flow paths.
- The bottom and sides should be lined with geotextile fabric to prevent migration of soil “fines” into the stone reservoir and reduce its storage capacity and ability to support the overlying pavement.
- The excavated reservoir should be filled with crushed, clean-washed, uniformly graded aggregate. Aggregate size is based on design and sized to maximize void space. Typical size is 1.5 inch to 2.5 inch aggregate.
- Water from the stone reservoir should not be allowed to infiltrate into material underlying adjacent conventional pavements as this could cause failure of the conventional pavement.

Pervious Concrete

- All permeable materials must meet applicable material quality specifications and requirements for compressive strength, water absorption, and freeze-thaw resistance. Mixes and/or installation methods should meet appropriate American Society for Testing and Materials standards for public-use surfaces like parking lots and roads. (As of March 2007, ASTM standards do not exist for pervious concrete; however, these are in the process of being established.)
- Ensure paving material infiltration rates are greater than the peak design rainfall intensity.
- Specially formulated mixture of Portland cement, water, and uniform, open-graded coarse aggregate.
- Adequate void space (15 to 25 percent) to allow rapid percolation of storm water runoff. The porosity rate can be correlated with the proposed land use and therefore may require design modification.
- Typically four to six inches thick (typically 25 percent thicker than a conventional Portland cement pavement designed for the same traffic volume; minimum thickness of six inches for commercial uses such as automobiles with no truck traffic).

Regional Adaptations

- In cold climates, the base of the stone reservoir should be below the frost line or the system should be designed to facilitate drainage of storm water away from the aggregate recharge bed to reduce the risk of frost heave.

Installation

The proper installation of pervious concrete systems is critical to its long-term performance as a storm water quality measure. Therefore, is important that the installation conform to concrete industry standards and specifications. In its on-going effort to educate and train installers, the concrete industry has developed a certification program. This program is designed to ensure that pervious concrete systems are designed and installed properly.

- Provide thorough construction oversight by trained individuals.
- Maintain erosion and sediment control measures until the site is stabilized. Active construction sites involve mass earthmoving and many activities that can generate sediment. It is often recommended to install these systems late in the construction phase of a project when there is less likelihood of sediment discharge. (Sedimentation that discharges onto a pervious concrete system can result in failure of the infiltration system or require higher maintenance.)
- Excavate the area for the stone reservoir, taking precautions to avoid compaction of the soil substrate and smearing of the exposed soil faces of the excavation. Scarify any areas where the soil face(s) has been smeared.
- Install geotextile fabric liner on the bottom and sides of the stone reservoir, overlapping adjoining rolls by 12 inches or more. If the system being installed is closed, install an appropriate impermeable membrane.
- Place aggregate as specified in the construction plans and compact in six-inch lifts.
- Install pavement materials to the dimensions and grades shown in the construction plans. Compact all pervious concrete materials to provide strength and resist densification under the intended traffic use.
- The same strike off equipment can be used as for conventional concrete, but finishing tools such as trowels and bullfloats should not be used. A heavy roller should be used to compress the material and to level the surface. Curing with a six millimeter plastic should begin within 20 minutes or less after material is discharged from the truck or as specified by concrete industry standards.
- Control joints are often used to prevent random cracking. However, due to the rough texture of the material joints are not always required. Control joints can be cut using a roller with a welded steel flange. Joints may also be cut with a saw, but the joints are less durable and there is more potential for raveling when saw cut. If joints are used to control cracking, the joints should be kept out of the vehicle wheel path as much as practicable. (Cracks in pervious concrete are less noticeable due to the texture of the pavement.)

- The surface must be continuously cured for a minimum of seven days with impervious sheeting such as six millimeter plastic or burlene. Liquid-sprayed curing materials may be used to supplement, but not to replace, the sheeting. Curing sheets must be secured to prevent removal during the curing period.

Maintenance

Pervious concrete systems require additional maintenance as compared to conventional concrete. Failure of these systems can usually be attributed to poor design, poor construction, and/or poor maintenance.

During construction, the pervious concrete system should be inspected several times and design specifications should be stringently followed and enforced.

These systems should also be inspected several times during the first few months following completion of construction to ensure that the system was installed correctly and is functioning properly. Regularly scheduled inspection and maintenance can be performed thereafter. The following table lists several routine maintenance activities and identifies recommended inspection and maintenance frequencies.

Measures should also be taken to avoid paving or resealing the pervious concrete surface with nonporous materials. Several options include but are not limited to signage on or adjacent to the pervious concrete surface and maintenance guidelines. It is important that those involved with maintenance of a pervious concrete system understand that maintenance is critical to the success of this measure. A carefully worded maintenance agreement should be developed that provides specific guidance about how to conduct routine maintenance and how the surface should be repaved. Where practical, signs identifying the pervious concrete system should be posted on or adjacent to the site [e.g., Pervious Concrete Pavement Used on this Site - DO NOT Resurface with Nonporous Material or Film Forming Sealers. Call (xxx) xxx-xxxx for more information.]

In addition to regularly scheduled maintenance, the life expectancy of pervious concrete systems can usually be increased by implementing a stringent sediment control plan, pretreating storm water runoff, and placing restrictions on use by heavy vehicles. In cold climates, limit the use of sand and gravel to prevent clogging and wear. Use of deicing agents should be minimized to protect ground water. If snow is to be removed by mechanical means, set the blade of the snow plow one to two inches above the surface of the pavement.

Table 1 lists several routine maintenance activities and identifies recommended inspection and maintenance frequencies.

Table 1: Maintenance for Pervious Concrete Systems

Activity	Schedule
Ensure the pavement is clean of debris and sediment.	Monthly
Ensure that pavement dewaters between storm events.	Monthly
Inspect for deterioration or spalling and repair per manufacturer's recommendations	Semiannually
Sweep with a vacuum street sweeper. Material removed should be disposed properly.	3 to 4 times per year
If clogging is identified, pressure wash surface (low or medium) to loosen sediment, followed by vacuum sweeping to remove the loosened material in the pores. Material removed should be disposed properly.	3 to 4 times per year
Evaluate all adjacent areas and seed any that are unvegetated or need maintenance.	3 to 4 times per year
Mow areas that drain to the pervious concrete system and remove grass clippings. Keep area clean of debris and other trash.	As needed

Source: Adapted from U.S. EPA, 1999g; Georgia Stormwater Management Manual, 2001

Costs

When pervious concrete systems are properly installed and maintained, they can be a valuable part of any storm water management system. Important issues to consider when doing a cost-benefit analysis include surrounding land use, amount of traffic, and the proximity and sensitivity of nearby watersheds.

The initial costs of pervious concrete systems are often competitive or slightly higher than conventional pavement systems. These costs can generally be attributed to site preparation, the proximity to gravel/stone supplies, and the use of specialized equipment. For example, installation of the stone reservoir is usually more expensive than construction of a conventional compacted sub-base associated with traditional pavement systems. However, some of the higher installation costs associated with pervious concrete systems can often be offset if the system is designed to fit the existing topography. This generally results in less earth-moving activity and fewer deep excavations than with conventional pavement systems. Installation costs can also be offset when the need for other types of storm water management measures such as storm water pipes, inlets, curbs and gutters, retention/detention basins, etc. are eliminated or their overall size is reduced.

Maintenance costs of pervious concrete systems are also generally higher than conventional pavement systems. The cost of vacuum sweeping and pressure washing of the pavement may be substantial if a community or facility owner does not already perform these types of operations in their maintenance program activities.

Additional Information

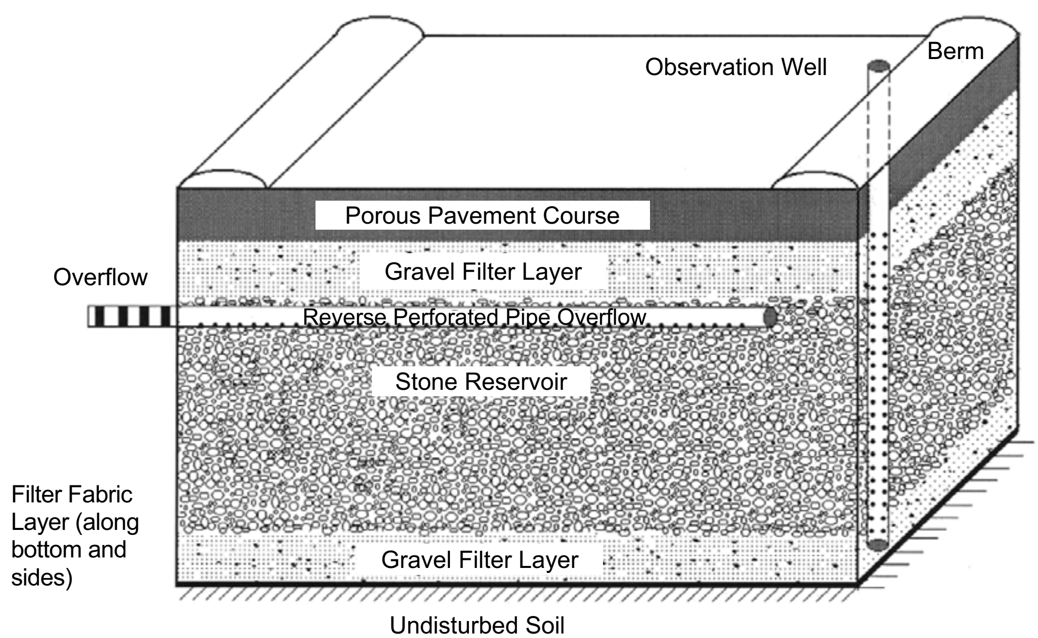
Internet Keyword Search:
porous pavement, porous pavement systems,

Porous Asphalt Systems

***Porous asphalt systems** are special types of pavement systems that allow rain and snowmelt to infiltrate through the pavement material and discharge into an underlying stone reservoir that temporarily stores the storm water runoff. The stored runoff is then allowed to infiltrate into the underlying soil material, discharge to an auxiliary drainage system, or discharge into a secondary storm water quality treatment device. Porous asphalt appears the same as its traditional counterpart but is manufactured without "fine" materials. The reduction in amount of fine materials allows for larger interconnected voids which in turn allows for storm water infiltration.*

Porous asphalt systems generally have an advantage over conventional pavement systems because they minimize the disruption of an area's hydrology, facilitate ground water recharge, and can provide water quality benefits. This is especially important in highly developed areas where the majority of the land surface is covered with concrete or asphalt pavement.

Figure 1: Diagram of Porous Pavement



Source: Adapted from Schueler, 1987

Application

There are several factors that dictate where porous asphalt systems can be used. These include but are not limited to soil type and seasonal high water table. These factors are directly related to site selection and design requirements that are discussed later in this section. One of the primary concerns that is associated with porous asphalt is its application in colder climates. Issues include winter maintenance activities as well as the potential for system failure due to frost heave. Maintenance is critical to the success or failure of these systems and is addressed later in the section. The potential for frost heave can be addressed through design modification that provides for an adequate base layer that will reduce this risk.

Pedestrian Areas

Porous asphalt systems are ideal for sidewalks and other pedestrian walkways, rollerblade and bike pathways, and areas such as patios and common areas around residential buildings.

Transportation Areas

Porous asphalt systems are well suited for the construction of lightly used access roads, overflow parking areas, and low-volume traffic areas around office buildings, recreational areas, and shopping centers. Other areas where porous asphalt systems may be used include emergency stopping areas, traffic islands, vehicle crossovers on divided highways, and shoulders along roadways, airport taxiways, and airport runways.

Porous asphalt systems are poorly suited for use in areas with high traffic volumes or areas with significant truck traffic. They are also poorly suited for use in areas where it is necessary to apply sand or other deicing agents to the pavement surface. Sand has a tendency to clog the surface of the pavement material, whereas other deicing agents may migrate into the ground water.

Ultra Urban Areas

Porous asphalt systems can be a good option in densely developed urban areas which typically have little pervious surface area. Porous asphalt systems in this kind of setting allow infiltration of storm water which in a conventional setting would be lost because of lack of permeable surface areas and efficient storm water drainage systems.

Storm Water Hotspots

Infiltration of storm water into the underlying soil material is not recommended to treat runoff from designated storm water hotspots due to the potential for ground water contamination. Porous asphalt systems should not be used for industrial and manufacturing sites where there is a high concentration of soluble pollutants, pesticides, fertilizers, and heavy metals. Storm water hotspots include areas such as gas/fueling stations, truck stops, vehicle service and maintenance areas, vehicle and equipment washing/steam cleaning facilities, auto recycling facilities, loading and unloading facilities, commercial storage areas, outdoor container storage areas, public works storage areas, commercial nurseries, marinas, hazardous material generators, and industrial rooftops because these areas are frequently subject to the high risk of ground water contamination.

Advantages

- Allows rain and snowmelt to pass through the pavement material.
- Provides water quality benefits by filtering pollutants (e.g., petroleum hydrocarbons, metals, organic matter, and nonpoint source pollutants such as phosphorous attached to fine soil particles) from storm water runoff via infiltration into the underlying soil substrate and through microbial action.
- Reduces the volume of storm water runoff and associated erosion potential.
- Attenuates peak discharge flows and reduces the amount of storm water entering storm drain systems.
- Provides some natural filtration capacity while maintaining the structural and functional features of the conventional pavement material it replaces.
- Stone reservoir can be lined with an impermeable liner, allowing storm water to be reused, stored, or treated through utilization of a secondary storm water treatment measure.
- Minimizes the disruption of the hydrology of an area by providing a reservoir and percolation field for surface water to re-enter ground aquifers, recharges low flow in streams during dry periods, and reduces downstream flooding.
- Minimizes the amount of land consumption by reducing the need for traditional storm water management structures, thereby saving open space for alternative uses.
- Minimizes construction and maintenance costs of street curbs and gutters, storm sewer systems typically required to carry storm water to an outfall, and other associated storm water management measures such as retention/detention ponds.
- Improves roadway safety by reducing noise, improving visibility in wet weather conditions, and reducing risk of skidding/hydroplaning.
- Same mixing and application equipment can be used as for conventional asphalt (only the formula for the paving material changes).

- Removal of fine particulates and soluble pollutants from storm water runoff via soil infiltration (degree of pollutant removal is related to the amount of runoff which exfiltrates the subsoil).

Disadvantages

- Pavement engineers and contractors may not possess the expertise and experience to apply this technology (generally requires special planning and expertise to install.)
- Potential for petroleum products to leach from asphalt and/or binder surface and contaminate ground water.
- Poorly suited for use in naturally occurring seasonal high water table soils.
- Poorly suited for use in wellhead protection areas.
- The pavement surface, if improperly installed and maintained, has a tendency to become clogged with particulate matter and debris.
- Not suitable for use in areas where materials applied to the roadway can clog or fill voids in the porous asphalt (e.g., chip and seal operations or application of sand to ice-covered roadways).
- Poses a risk to ground water contamination. For example, pollutants such as nitrates and chlorides that are not easily trapped, absorbed, or reduced may continue to move through the soil profile and into ground water (dependant on soil conditions and aquifer susceptibility).
- Potential risk for vehicle fuels, oils, greases, and other substances to leak onto the pavement and leach into ground water.
- May cause frost heave of pavement if system is improperly designed, installed, or maintained. Porous asphalt systems typically have higher maintenance requirements than conventional pavement systems.
- Local building codes may restrict the use of porous asphalt systems without special approval or variances.
- Amount of asphalt binder required is about six percent by weight, which is somewhat higher than required for standard conventional asphalt.
- Has less shear strength capability because of the reduced amount of "fines."

Performance

The initial performance of porous asphalt systems has been very good. However, according to the U.S. Environmental Protection Agency the failure rate over time has been high. Failure has been attributed to poor design, inadequate construction techniques, poor siting, and poor maintenance. When these issues are addressed, it is anticipated that these systems can have a minimum service life of 20 years.

Properly designed, installed, and maintained porous asphalt systems can be cost effective and provide a storm water management system that promotes infiltration and the removal of pollutants from storm water runoff flowing through the system. Pollutant removal mechanisms associated with these systems include absorption, straining, and microbiological decomposition. Pollutant removal effectiveness will vary depending on system design, soil substrate characteristics, and proper maintenance of the system. Sampling data for these systems, although limited, indicate a relatively high removal rate for total suspended solids, metals, and oil and grease.

Design Specifications

Sitting, design, installation, and maintenance of porous asphalt systems are critical if they are to function properly and efficiently. Therefore, porous asphalt systems, and especially the storm water component, should be designed by a professional proficient in hydrology and storm water design. Design and installation should be in conformance with industry standards and specifications.

Information in this section was assembled from a variety of sources including the U.S. Environmental Protection Agency's storm water technical fact sheet entitled *Porous Pavement* (1999h); the U.S. EPA's post-construction storm water management in new development and redevelopment fact sheet entitled *Porous Pavement* (2002k); the Michigan Department of Environmental Quality, Surface Water Quality Division's *Guidebook of Best Management Practices for Michigan Watersheds* (reprinted October, 1998); and the Georgia Stormwater Management Manual (2001).

Porous asphalt systems should include basic features in the design including but not limited to pretreatment, treatment, conveyance, and landscaping.

Pretreatment

Pretreatment should be considered, and is especially recommended, where oil and grease or other potential ground water contaminants are expected. In most porous asphalt system designs the pavement itself is considered to act as the first level of storm water runoff pretreatment. The fine aggregate layer immediately beneath the pavement and above the stone reservoir is generally considered as a secondary pretreatment element in the overall system. Effectiveness of both of these pretreatment measures is marginal at best. System designers should take into account the pollutants associated with the land use and apply appropriate pretreatment measures to target specific pollutants.

Adjacent areas that drain to the porous asphalt system should be stabilized and/or designed so that runoff from the adjacent area will not deposit sediment on the asphalt surface. Otherwise, frequent maintenance of the pavement surface is critical to prevent clogging.

Treatment

A stone reservoir, which lies immediately beneath the pavement and filter course, should be designed and sized to attenuate and treat a small storm water runoff event (typically 0.5 inch to 1.5 inches). Storage capacity must be designed around the amount of air/pore space in the reservoir since this is the only area where water can be stored.

Conveyance

Porous asphalt systems need some method of conveying storm water runoff through the system. Pores in the asphalt and filter course allow storm water to infiltrate into the underlying stone reservoir. Water stored in the stone reservoir is then allowed to either infiltrate into the underlying soil substrate or be held in an underground impermeable closed system that discharges to a secondary storm water management/treatment measure via subsurface drainage pipes. Porous asphalt systems should be designed with some method to convey large storm events to the underlying stone reservoir. Setting storm drain inlets at strategic locations within the system design will allow larger storm water flows to enter the stone reservoir in the event that the infiltration rate of the pavement is insufficient to handle the storm event or the pavement surface becomes clogged.

Landscaping

Preventing sediment loads from clogging the porous asphalt surface is critical if the system is to function properly. Therefore, it is important to develop and implement a landscaping plan that will ensure that the contributing drainage area is stabilized.

Design of porous asphalt systems also requires evaluation and incorporation of several key elements such as, but not limited to, soil type, infiltration rate, depth to a limiting layer (e.g., bedrock, a seasonal high water table, glacial till), slope length and gradient, construction materials, and installation methods. Following are several key design specifications that should be considered and evaluated when siting, designing, and installing porous asphalt systems.

Siting

- Select infiltration opportunities within the immediate development area.
- Avoid conveying storm water long distances.
- Consider past use of the site and appropriateness of infiltration design with porous asphalt.
- Consider the source of the storm water runoff to be treated.
- Poorly suited for use in naturally occurring seasonal high water table soils.

- Minimum setback of 100 feet from wells used to supply drinking water. State rules or local ordinances may require distances greater than 100 feet.
- Minimum setback of 100 feet up-gradient of building foundations. Local building codes may dictate setback requirements.
- Minimum setback of 10 feet down-gradient of building foundations. Local building codes may dictate setback requirements.
- Poorly suited for use in wellhead protection areas.
- These systems are not suitable in areas with karst geology without adequate geotechnical assessment by qualified individuals. System placement and design may also be subject to local requirements or ordinances.
- The application for porous asphalt systems should not exceed five percent. Applications are best on flatter areas.
- Soil Substrate
  - Perform site tests to determine depth to seasonal high water table, depth to bedrock, and soil limitations, including infiltration capabilities.
  - Soils should be homogeneous and should not have any compacted layers.
  - For optimal performance, locate systems on deep, well-drained, permeable soils. Soil should have field-verified permeability rates between one-half and three inches per hour or silt/clay contents of less than 40 percent and be in U.S. Department of Agriculture Natural Resources Conservation Service hydrologic groups A or B. Permeability rates of less than one-half inch per hour and soils with higher clay content can be accommodated through special design.

General Design Considerations

The design of porous asphalt consists of at least four layers: a layer of asphalt, a filter layer, a reservoir layer, a second filter layer (optional), and a layer of geotextile material. Porous asphalt consists of standard bituminous asphalt in which the fines have been screened and reduced, creating void space to make it permeable to water. The void space of porous asphalt is approximately 16 percent to 18 percent, as opposed to two percent to three percent for conventional asphalt.

- Contributing impervious surface to porous asphalt system ratio should be no more than 3:1.
- Design to minimize amount of storm water runoff porous asphalt system receives from adjacent areas. If necessary divert runoff from adjacent areas into the stone reservoir before it reaches the porous pavement surface. This can be done by incorporating an unpaved stone edge at the perimeter of the

pavement or installing catch basins designed to discharge into the stone reservoir. (Note: The unpaved stone perimeter and/or catch basins can also act as an emergency entrance/spillway that will allow storm water runoff to enter the stone reservoir in the event that the porous asphalt surface becomes paved over, clogged, or forgotten.)

- Design the system to contain spills.
- Avoid excessive cut and fill earthwork by designing the system to fit the contours of the site.
- Use quality base and sub-base materials that can serve as the wearing course for the intended use and in the case of traffic, support the applied loads.
- Use sufficient pavement thickness to protect the subgrade from being overstressed.
- Do not infiltrate stored storm water runoff into compacted fill because the permeability will often be too slow.
- Place observation wells downstream of the porous asphalt system.

Geotextile Fabric Liner

- Nonwoven geotextile fabric of at least four-ounce weight to allow water to drain into the soil while preventing soil particles from moving into the stone bed.
- Placed on uncompacted natural soil.
- Placed flush with soil surface (bottom and sides) of excavated stone reservoir and overlapped a minimum 12 inches between adjoining rolls.

Stone Reservoir

- Size and depth of reservoir is determined by soil infiltration rate, total impervious surface area (i.e., contiguous impervious roadways and streets, rooftops, etc.) drained into the reservoir, design storm event, and frost line depth.
- Twelve-hour minimum and 72-hour maximum draw-down time with a recommended draw-down time of 24 to 48 hours. (Note: Microbiological decomposition can be impeded if soils are unable to dry out and anaerobic conditions are allowed to develop between storm events.)
- Design storage capacity should not include those areas above the pavement. Storage volumes should be restricted to the stone reservoir for the system. Designers may also choose to exclude the porous asphalt as part of the design storage capacity based on industry specifications and regional climatic issues and the potential for frost heave.

- It is also important to design porous asphalt systems with a mechanism to discharge water from the stone reservoir in the event that its design storage capacity is exceeded. An exfiltration system should be incorporated into a system that is installed in soils with a permeability rate of less than one-half inch per hour or with a high clay content. The stone reservoir component of porous asphalt systems must be designed with an exfiltration system that allows large storm events to bypass the reservoir and prevent saturation of the overlying pavement. Bypass of excess water in the stone reservoir is typically accomplished in one of three ways: full exfiltration, partial exfiltration, or water quality exfiltration.

  - Full Exfiltration System – The stone reservoir is an enclosed system (i.e., no pipe outlets) that only allows runoff to exit the system via infiltration into the soil substrate. The reservoir storage capacity must be large enough to accommodate the entire runoff volume from the design storm. An aboveground emergency overflow channel such as a swale or raised curb is used to collect excess runoff from storm events greater than the design storm and divert it to an auxiliary storm water treatment device.
  - Partial Exfiltration System – The stone reservoir is connected to an underground drainage system that includes regularly spaced, perforated pipes located in shallow depressions. The pipes collect the stored runoff and direct it to an infiltration basin or a central outlet. Size and spacing of the under-drain system should allow for passage of the design storm event.
  - Water Quality Exfiltration System – The stone reservoir is designed to store the first flush (i.e., volume of runoff produced by a one inch storm event or the design storm event) of runoff volume from the design storm event. Runoff volumes in excess of the first flush are not treated by the porous asphalt system, but are conveyed to a conventional storm water treatment measure.

- The bottom of the reservoir should be a minimum of three feet above any limiting layer (e.g., seasonal high water table, glacial till, bedrock).
- The base of the reservoir should be extended below the frost line to reduce the risk of frost heave.
- The bottom of the reservoir should be designed to allow water to infiltrate over the largest area possible. (Note: A good rule-of-thumb is a ratio of 5:1 impervious surface area to infiltration area.)
- The bottom of the reservoir should be level to allow even distribution and infiltration of storm water and prevent the development of preferential flow paths.

- The bottom and sides should be lined with geotextile fabric to prevent migration of soil "fines" into the stone reservoir and reduce its storage capacity and ability to support the overlying pavement.
- The excavated reservoir should be filled with crushed, clean-washed, uniformly graded aggregate to maximize void space. Aggregate size is dependent on design criteria, but is typically 1.5 inch to 2.5 inch aggregate.
- Water from the stone reservoir should not be allowed to infiltrate into material underlying adjacent conventional pavements as this could cause failure of the conventional pavement.

Filter Course

- Placed on top of stone reservoir to lock up the surface of the stone substrate and provide a firm platform for the paving material.
- Crushed, clean-washed, uniformly graded aggregate. Size is based on design standards, but is typically one-half inch aggregate.
- Typically one to two inches thick.

Porous Asphalt

- All permeable materials must meet applicable material quality specifications and requirements for compressive strength, water absorption, and freeze-thaw resistance. Mixes and/or installation methods should meet appropriate American Society for Testing and Materials standards for public-use surfaces like parking lots and roads.
- Industry standards also specify 85 percent to 100 percent penetration grade to prevent surface scuffing by vehicle wheels.
- Standard bituminous asphalt mixture in which the aggregate fines (particles smaller than 600 micrometers, or the No. 30 sieve) have been screened and reduced.
- Sufficient bituminous asphalt content, typically 5.5 percent to 6 percent based on total weight to ensure pavement durability.
- Ensure paving material infiltration rates are greater than the peak design rainfall intensity.
- Polymers and/or fibers can be used in the asphalt mixture to regulate or control drain-down time and improve durability and shear strength.
- The thickness of the pavement will be based on design requirements. A typical application is two to four inches thick, or according to industry standards.

Regional Adaptations

- In cold climates, the base of the stone reservoir should be below the frost line or the system should be designed to facilitate drainage of storm water away from the aggregate recharge bed to reduce the risk of frost heave.

Installation

Installation of porous asphalt systems is critical to its long-term performance as a storm water quality measure. Therefore, it is important that the installation conform to industry standards and specifications and that installers are trained. These systems are susceptible to failure, which can be costly and compromise water quality.

- Provide thorough construction oversight.
- Maintain erosion and sediment control measures until the site is stabilized. Active construction sites involve mass earthmoving and many activities that can generate sediment. It is often recommended to install these systems late in the construction phase of a project when there is less likelihood of sediment discharge. (Sedimentation that discharges onto a porous asphalt system can result in failure of the infiltration system.)
- Excavate the area for the stone reservoir, taking precautions to avoid compaction of the soil substrate and smearing of the exposed soil faces of the excavation. Scarify any areas where the soil face(s) has been smeared.
- Install geotextile fabric liner on the bottom and sides of the stone reservoir, overlapping adjoining rolls by 12 inches or more. If the system being installed is closed, install an appropriate impermeable membrane.
- Place aggregate and install pavement materials to the dimensions and grades shown in the construction plan.
- Install filter course as specified in the construction plan.
- Placement of the porous asphalt should occur when air temperature is above 50 degrees. The temperature of the paving material should range from 230 to 260 degrees.
- Install pavement material to the dimensions specified in the construction plan.
- Roll the asphalt using a traditional roller (typically one to two passes). Excessive rolling may reduce the infiltration capacity of the pavement.
- Compact all porous asphalt materials to provide strength and resist densification under the intended traffic use.

- Traffic should be restricted from the area for a minimum of one day. Additional time may be required based on intended use of the pavement area.

Maintenance

Porous asphalt systems require additional maintenance as compared to conventional asphalt. Failure of these systems can usually be attributed to poor design, poor construction, and/or poor maintenance.

During construction, the porous asphalt system should be inspected several times and design specifications should be stringently followed and enforced.

These systems should also be inspected several times during the first few months following completion of construction to ensure that the system was installed correctly and is functioning properly. Regularly scheduled inspection and maintenance can be performed thereafter. The following table lists several routine maintenance activities and identifies recommended inspection and maintenance frequencies.

Table 1: Maintenance for Porous Asphalt Systems

Activity	Schedule
	Porous Asphalt
Ensure the pavement is clean of debris and sediment.	Monthly
Ensure that pavement dewaters between storm events.	Monthly
Inspect for potholes and cracks and repair according to industry standards.	Semiannually
Sweep with a vacuum street sweeper. Properly dispose of material.	Three to four times per year
Vacuum sweep and properly dispose of removed material followed by high-pressure washing to free pores in the pavement from clogging.	Three to four times per year
Evaluate all adjacent areas and seed any that are unvegetated or need maintenance.	Three to four times per year
Mow areas that drain to the porous asphalt system and remove grass clippings. Keep area clean of debris and other trash.	As needed

Source: Adapted from U.S. EPA, 1999g; Georgia Stormwater Management Manual, 2001

Measures should also be taken to avoid paving or resealing the porous asphalt with nonporous materials. Several options include but are not limited to signage on or adjacent to the porous asphalt surface and maintenance guidelines.

It is important that those involved with maintenance of a porous asphalt system understand that maintenance is critical to the success of this measure. A carefully worded maintenance agreement should be developed that provides specific guidance about how to conduct routine maintenance and how the surface should be repaved. Where practicable, signs identifying the porous asphalt system should be posted on or adjacent to the site [e.g., Porous Asphalt Pavement Used on this Site—DO NOT Resurface with Nonporous Material or Film Forming Sealers. Call (xxx) xxx-xxxx for more information].

In addition to regularly scheduled maintenance, the life expectancy of porous asphalt systems can usually be increased by implementing a stringent sediment control plan, pretreating storm water runoff, and placing restrictions on use by heavy vehicles. In cold climates, limit the use of sand and gravel to prevent clogging and wear. Use of deicing agents should be minimized to protect ground water. If snow is to be removed by mechanical means, set the blade of the snow plow one to two inches above the surface of the pavement.

Costs

When porous asphalt systems are properly installed and maintained, they can be a valuable part of any storm water management system. Important issues to consider when doing a cost-benefit analysis include surrounding land use, amount of traffic, and the proximity and sensitivity of nearby watersheds.

The initial costs of porous asphalt systems are often competitive or slightly higher than conventional pavement systems. These costs can generally be attributed to site preparation, the proximity to gravel/stone supplies, and the use of specialized equipment. For example, installation of the stone reservoir is usually more expensive than construction of a conventional compacted sub-base associated with traditional pavement systems. However, some of the higher installation costs associated with porous asphalt systems can often be offset if the system is designed to fit the existing topography. This generally results in less earth moving activity and fewer deep excavations than with conventional pavement systems. Installation costs can also be offset when the need for other types of storm water management measures such as storm water pipes, inlets, curbs and gutters, retention/detention basins, etc. are eliminated or their overall size is reduced.

Maintenance costs of porous asphalt systems are also generally higher than conventional pavement systems. The cost of vacuum sweeping and pressure washing of the pavement may be substantial if a community or facility owner does not already perform these types of operations in their maintenance program activities.

Additional Information

Internet Keyword Search:
porous pavement, porous pavement systems, porous asphalt, and pervious asphalt

Porous Paver Systems

Figure 1: Installation of a Permeable Paving System

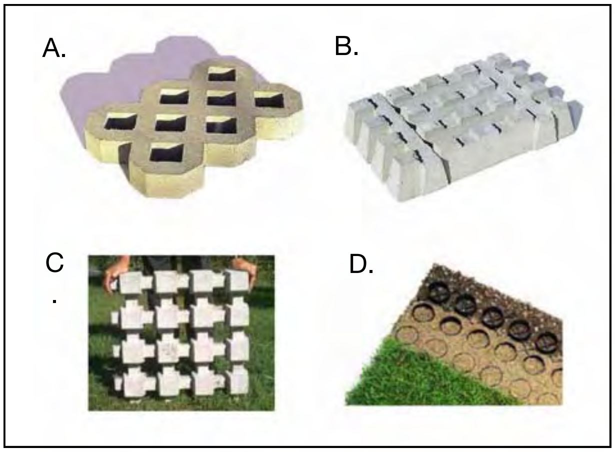
Source: Low Impact Development Center

Porous paver systems *consist of structural modular units that are designed with voids. These systems allow infiltration of storm water runoff into an underlying aggregate substrate reservoir. Water in the aggregate reservoir is allowed to infiltrate into the surrounding subsoil, discharged to a secondary storm water treatment device, or it can be discharged into an auxiliary storm water drainage system.*

Porous paver systems are a useful storm water management measure because they minimize the disruption on the hydrology of an area, facilitate ground water recharge, and provide water quality benefits. This is especially important in highly developed areas where the majority of the land surface is covered with concrete and asphalt pavement.

Porous pavers include a variety of commercially available products that include but are not limited to concrete paving blocks, modular lattice units, or cast in place concrete grids. Modular concrete paving blocks consist of interlocking concrete units with void spaces. Modular lattice systems typically consist of plastic grids that are either in individual units or can be unrolled, cut to size, and stretched out or expanded. Cast in place systems consist of pouring concrete in place, with openings or gaps incorporated into the system. Cast in place systems can provide additional structural capacity. The void spaces in all of these systems can either be filled with aggregate or filled with soil material and vegetated. Porous paver systems are typically placed over an aggregate substrate to prevent uneven settling of the paver units.

Figure 2: Examples of Modular Porous



Key
A. Concrete Paver Block
B. Castellated Block
C. Lattice Block
D. Grass/Gravel Paver Mat

Source: Georgia Stormwater Management Manual, 2001

Application

Porous paver systems are generally used in conjunction with alternative site design or low impact development techniques to reduce storm water runoff volumes and pollutant loads. Porous paver systems are well suited for use in low traffic areas (generally 500 average daily trips or less), parking lots (i.e., overflow parking for malls, arenas, etc.), residential and commercial driveways, walkways, paths, patios, emergency lanes, and some roadside rights-of-way. These systems are also very useful in storm water management applications where space is limited.

Infiltration of storm water into the underlying soil material is not recommended to treat runoff from designated storm water hotspots due to the potential for ground water contamination. Porous paver systems should not be used for industrial and manufacturing sites where there is a high concentration of soluble pollutants, pesticides, fertilizers, and heavy metals. Storm water hotspots include areas such as gas/fueling stations, truck stops, vehicle service and maintenance areas, vehicle and equipment washing/steam cleaning facilities, auto recycling facilities, loading and unloading facilities, commercial storage areas, outdoor container storage areas, public works storage areas, commercial nurseries, marinas, hazardous material generators, and industrial rooftops because these areas are frequently subject to the high risk of ground water contamination.

Advantages

- Allows rain and snowmelt to pass through the voids of the paving system.
- Provides water quality benefits by filtering pollutants.
- Reduces the volume of storm water runoff and associated erosion potential.

- Attenuates peak discharge flows and reduces the amount of storm water entering storm drain systems.
- Provides some natural filtration capacity while maintaining the structural and functional features of the conventional pavement material it replaces.
- Stone reservoir can be lined with an impermeable liner, allowing storm water to be reused, stored, or treated through utilization of a secondary storm water treatment measure.
- Minimizes the disruption of the hydrology of an area by providing a reservoir and percolation field for surface water to re-enter ground water aquifers, recharges low flow in streams during dry periods, and reduces downstream flooding.
- Minimizes the amount of land consumption by reducing the need for traditional storm water management structures, thereby saving open space for alternative uses.
- Minimizes construction and maintenance costs of street curbs and gutters, storm sewer systems typically required to carry storm water to an outfall, and other associated storm water management measures such as retention/detention ponds.
- Aesthetically pleasing.
- When damaged, or clogged, small areas can be easily replaced.

Disadvantages

- Requires design and installation by experienced engineers and contractors.
- More costly than conventional pavement due to materials and installation.
- Requires soil infiltration rate of one-half inch per hour or greater.
- Snow removal is difficult since snow plow blades can damage or dislodge paver units, sand application can lead to premature clogging, and salt can result in ground water contamination.
- Not suitable for use in wellhead protection areas.
- Not suitable for areas that require wheelchair access.
- Poorly suited for use in naturally occurring seasonal high water table soils.
- The pavement surface, if improperly installed and maintained, has a tendency to become clogged with particulate matter and debris.
- Poses a risk to ground water contamination. For example, pollutants such as nitrates and chlorides that are not easily trapped, absorbed, or reduced may

continue to move through the soil profile and into ground water (dependant on soil conditions and aquifer susceptibility).

- Potential risk for vehicle fuels, oils, greases, and other substances to leak onto the pavement and leach into ground water.
- May cause frost heave of pavement if system is improperly designed, installed, or maintained.
- Typically have higher maintenance requirements than conventional pavement systems.
- Local building codes sometimes restrict the use of these systems without special approval or variances.

Performance

The initial performance of porous paver systems has been very good. The failure rate over time has been high. Failure has been attributed to poor design, inadequate construction techniques, poor siting, and poor maintenance.

Properly designed, installed, and maintained porous paver systems can be cost effective and provide a storm water management system that promotes infiltration and the removal of pollutants from storm water runoff flowing through the system. Pollutant removal mechanisms associated with these systems include absorption, straining, and microbiological decomposition. Pollutant removal effectiveness will vary depending on system design, soil substrate characteristics, and proper maintenance of the system. Sampling data for these systems,

Design Specifications

Design of porous paver systems is critical if they are to function properly and efficiently. Following are some basic requirements for the design and installation of porous paver systems.

Information in this section was assembled from a variety of sources including the U.S. Environmental Protection Agency's post-construction storm water management in new development and redevelopment fact sheet entitled *Alternative Pavers* (2002l); Metropolitan Council Environmental Services' *Minnesota Urban Small Sites BMP Manual* (2001); and the Georgia Stormwater Management Manual (2001).

Pretreatment

Pretreatment should be considered, and is especially recommended, where oil and grease or other potential ground water contaminants are expected. System designers should take into account pollutants that are associated with the land use and apply appropriate pretreatment measures to target specific pollutants.

Adjacent areas that drain to a porous paver system should be stabilized and/or designed so that runoff from an adjacent area will not deposit sediment onto the porous paver surface. Otherwise, frequent maintenance of the pavement surface is critical to prevent clogging.

Treatment

A stone reservoir should be incorporated into systems where soil conditions are not favorable to promote infiltration. The reservoir, which lies immediately beneath the pavement, should be designed and sized to attenuate and treat a small storm water runoff event (typically 0.5 inch to 1.5 inches). Storage capacity must be designed around the amount of air/pore space in the reservoir since this is the only area where water can be stored.

Conveyance

Porous paver systems require some method of conveying storm water runoff through the system. Voids in the porous pavers allow storm water to infiltrate into the underlying stone reservoir. Water stored in the stone reservoir is then allowed to either infiltrate into the underlying soil substrate or be held in an underground impermeable closed system that discharges to a secondary storm water management/treatment measure via subsurface drainage pipes.

Porous paver systems should be designed with some method to convey large storm events to the underlying stone reservoir. Setting storm drain inlets at strategic locations within the system design will allow larger storm water flows to enter the stone reservoir in the event that the infiltration rate of the pavement is insufficient to handle the storm event or the surface becomes clogged.

Landscaping

Preventing sediment loads from clogging the porous paver surface is critical if the system is to function properly. Therefore, it is important to develop and implement a landscaping plan that will ensure that the contributing drainage area is stabilized. This is especially true during active construction, but is also applicable for post-construction activities.

Design of porous paver systems also requires evaluation and incorporation of several key elements such as, but not limited to, soil type, infiltration rate, depth to a limiting layer (e.g., bedrock, a seasonal high water table, glacial till), slope length and gradient, construction materials, and installation methods. Following are several key design specifications that should be considered and evaluated when siting, designing, and installing porous paver systems.

Siting

- Select infiltration opportunities within the immediate development area.
- Avoid conveying storm water long distances.
- Consider the source of the storm water runoff to be treated.
- Poorly suited for use in wellhead protection areas.
- Minimum setback of 100 feet from wells used to supply drinking water. State rules or local ordinances may require distances greater than 100 feet.
- Minimum setback of 100 feet up-gradient of building foundations. Local building codes may dictate setback requirements.
- Minimum setback of 10 feet down-gradient of building foundations. Local building codes may dictate setback requirements.
- Poorly suited for use in naturally occurring seasonal high water table soils.
- These systems are not suitable in areas with karst geology without adequate geotechnical assessment by qualified individuals. System placement and design may also be subject to local requirements or ordinances.
- Soil Substrate
  - Perform site tests to determine depth to seasonal high water table, depth to bedrock, and soil limitations, including infiltration capabilities.
  - Soils should be homogeneous and should not have any compacted layers.
  - For optimal performance, locate systems on deep, well-drained, permeable soils. Soil should have field-verified permeability rates between one-half and three inches per hour or silt/clay contents of less than 40 percent and be in U.S. Department of Agriculture Natural Resources Conservation Service hydrologic groups A or B. Permeability rates of less than one-half inch per hour and soils with higher clay content can be accommodated through special design.
- The ideal application of porous paver systems is typically on slopes of two percent or less.

General Design Considerations

Typical design of porous paver systems include geotextile liner, stone reservoir, geotextile liner (optional), a bedding course, and finally the paver.

- Design based on likely traffic loadings and projected life of the system.

To achieve performance, the following criteria should be applied:

- ■ Subgrade to sustain traffic loading.
- ■ Granular capping and sub-base layers should have sufficient load bearing to provide an adequate base for the overlying pavement selected.
- ■ Materials chosen should not crack or be subject to rutting. This is controlled by horizontal tensile stress at the base of these layers.

- The slope limitation may be overcome through terracing the porous paver system.
- Do not infiltrate stored storm water runoff into compacted fill because the permeability will often be too slow.
- Place observation wells downstream of the porous paver system.

Geotextile Fabric Liner

- Nonwoven geotextile fabric of at least four ounce weight to allow water to drain into the soil while preventing soil particles from moving into the stone reservoir.
- Placed on uncompacted natural soil.
- Placed flush with soil surface (bottom and sides) of excavated stone reservoir and overlapped a minimum of 12 inches between adjoining rolls.

Stone Reservoir

- Size and depth of reservoir is determined by soil infiltration rate, total impervious surface area (i.e., contiguous impervious roadways and streets, rooftops, etc.) drained into the reservoir, design storm event, and frost line depth.
- Depth of reservoir is based on design storage capacity and land use. Typically, the minimum reservoir depth is nine inches.
- Twelve-hour minimum and 72-hour maximum draw-down time with a recommended draw-down time of 24 to 48 hours. (Note: Microbiological decomposition can be impeded if soils are unable to dry out and anaerobic conditions are allowed to develop between storm events.)
- Design storage capacity <u>should not</u> include those areas above the pavement. Designers should also exclude the porous pavers as part of the design storage capacity.
- It is also important to design porous paver systems with a mechanism to discharge water from the stone reservoir in the event that its design storage capacity is exceeded. An exfiltration system should be incorporated into a

system that is installed in soils with a permeability rate of less than one-half inch per hour or with a high clay content. The stone reservoir component of porous paver systems must be designed with an exfiltration system that allows large storm events to exit the reservoir. Drainage of excess water in the stone reservoir is typically accomplished in one of three ways: full exfiltration, partial exfiltration, or water quality exfiltration.

- Full Exfiltration System – The stone reservoir is an enclosed system (i.e., no pipe outlets) that only allows runoff to exit the system via infiltration into the soil substrate. The reservoir storage capacity must be large enough to accommodate the entire runoff volume from the design storm. An aboveground emergency overflow channel such as a swale or raised curb is used to collect excess runoff from storm events greater than the design storm and divert it to an auxiliary storm water treatment device.
- Partial Exfiltration System – The stone reservoir is connected to an underground drainage system that includes regularly spaced, perforated pipes located in shallow depressions. The pipes collect the stored runoff and direct it to an infiltration basin or a central outlet. Size and spacing of the under-drain system should allow for passage of the design storm event.
- Water Quality Exfiltration System – The stone reservoir is designed to store the first flush (i.e., volume of runoff produced by a one-inch storm event or the design storm event) of runoff volume from the design storm event. Runoff volumes in excess of the first flush are not treated by the porous paver system, but are conveyed to an auxiliary or secondary storm water treatment measure.

- The bottom of the reservoir should be a minimum of three feet above any limiting layer (e.g., seasonal high water table, glacial till, bedrock).
- The base of the reservoir should be extended below the frost line to reduce the risk of frost heave.
- The bottom of the reservoir should be level to allow even distribution and infiltration of storm water and prevent the development of preferential flow paths.
- The bottom and sides should be lined with geotextile fabric to prevent migration of soil "fines" into the stone reservoir and reduce its storage capacity and ability to support the overlying pavement.
- The excavated reservoir should be filled with crushed, clean-washed, uniformly graded aggregate. Aggregate size is based on design and sized to maximize void space. Typically, aggregate size is 1.5 inches to 2.5 inches.

- Water from the stone reservoir should not be allowed to infiltrate into material underlying adjacent conventional pavements as this could cause failure of the conventional pavement.

Paver

- The type of paver should be selected based on the intended land use and the overall objective of the project.
- The contributing impervious surface to porous paver system ratio should be no more than 3:1.
- Design to minimize amount of storm water runoff the porous paver system receives from adjacent areas. If necessary divert runoff from adjacent areas into the stone reservoir before it reaches the porous paver surface. This can be done by incorporating an unpaved stone edge at the perimeter of the pavement or installing catch basins designed to discharge into the stone reservoir. (NOTE: The unpaved stone perimeter and/or catch basins can also act as an emergency entrance/spillway that will allow storm water runoff to enter the stone reservoir in the event that the porous paver becomes paved over, clogged, or forgotten.)
- Design the system to contain spills.
- Ensure paving material infiltration rates are greater than the peak design rainfall intensity.
- The porosity rate can be correlated with the proposed land use and therefore may require design modification.

Regional Adaptations

- In cold climates, the base of the stone reservoir should be below the frost line or the system should be designed to facilitate drainage of storm water away from the aggregate recharge bed to reduce the risk of frost heave.

Installation

Proper installation of porous paver systems is critical to its long-term performance as a storm water quality measure. Therefore, it is important that the installation conform to industry standards and specifications.

- Provide thorough construction oversight by trained individuals.
- Maintain erosion and sediment control measures until the site is stabilized. Active construction sites involve mass earthmoving and many activities that can generate sediment. It is often recommended to install these systems late in the construction phase of a project when there is less likelihood of sedi-

ment discharge. (Sedimentation that discharges onto a porous paver system can result in failure of the infiltration system or require higher maintenance.)

- Excavate the area for the stone reservoir, taking precautions to avoid compaction of the soil substrate and smearing of the exposed soil faces of the excavation. Scarify any areas where the soil face(s) has been smeared.
- Install geotextile fabric liner on the bottom and sides of the stone reservoir, overlapping adjoining rolls by 12 inches or more. If the system being installed is closed, install an appropriate impermeable membrane.
- Place aggregate as specified in the construction plans. The aggregate should be placed in lifts and slightly compacted.
- Install geotextile liner (optional) based on design requirements and product.
- Install bedding course.
- Install pavers to the dimensions and grades shown in the construction plans.
- Infill should be based on use. Masonry sand has a high infiltration rate and is typically used when vegetation is not placed. Sandy loam material is preferred for areas where vegetation is planned.
- For systems that are to be vegetated, exclude traffic from the porous paver system for at least one month after planting to allow for establishment of a dense stand of vegetation.

Maintenance

Maintenance of porous paver systems is relatively minimal but absolutely necessary to ensure efficient and proper operation of the system. Inspection of these systems should occur monthly for the first few months after installation. Inspection frequency can be extended once it is determined that the system is stable and functioning properly. Failure of these systems is often attributed to poor design, poor construction, heavy vehicular traffic, and poor maintenance.

Table 1 contains several recommended maintenance guidelines. The system manufacturer or designer may have alternative or specific requirements based on the system that has been installed.

Table 1: Maintenance for Porous Paver Systems

Activity	Schedule
Inspect for settling of paver units.	Minimum of every three months
Ensure that system dewaters between storms.	Monthly
Inspect voids to ensure they are not clogged with debris and the material filling the voids is level with the top of the paver system.	Minimum of every three months
Clean organic material (leaves, etc.) from surface with vacuum or by low-pressure washing.	Three to four times per year
Inspect for deterioration or spalling.	Annually
Evaluate all adjacent areas and seed any that are unvegetated or need maintenance.	Three to four times per year
Mow areas that drain to the porous paver system and remove grass clippings.	As needed

Source: Georgia Stormwater Management Manual, 2001

Costs

Porous paver systems are expensive to install. However, when these systems are properly installed and maintained, they can be a valuable part of any storm water management system. Important issues to consider when doing a cost-benefit analysis include surrounding land use, amount of traffic, and the proximity and sensitivity of nearby watersheds. The failure rate of porous paver systems also needs to be taken into consideration when evaluating the costs of these systems.

Additional Information

Internet Keyword Search:
porous pavers, permeable pavers, porous paver systems, permeable paver systems, paver systems

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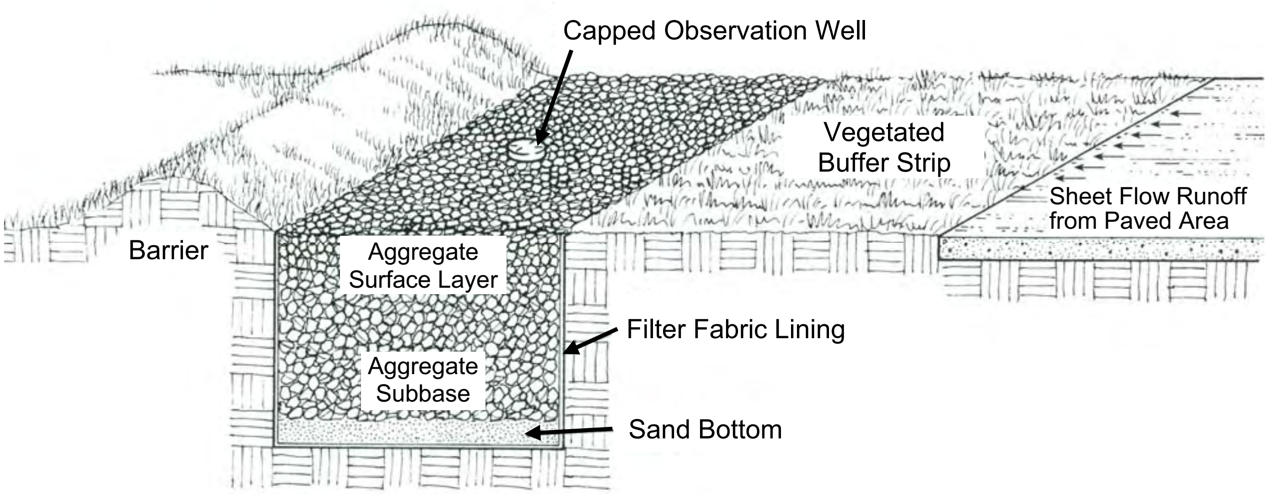
Infiltration Trench

***Infiltration trenches** are shallow, excavated, stone-filled trenches that collect and store storm water runoff. The runoff that is collected in the stone reservoir is allowed to infiltrate into the underlying soil. Pollutants are removed through adsorption, filtering, and bacterial degradation. In addition to pollutant removal, they are installed to reduce runoff volume, provide ground water recharge, and preserve the base flow in nearby water courses. Infiltration trenches are not intended for removal of sediments, which may clog the trench. Excess sediments should be removed in advance through adjacent storm water quality measures such as grass swales, vegetative filter strips, sediment forebay ponds, sediment traps, etc.*

Figure 1: Diagram of an Infiltration Trench Installed in Conjunction With Other Storm Water Management Measures



Source: Lowndes, M.A., 2000, Adapted from Maryland Department of the Environment, Sediment and Storm Water Administration, 1985

Application

There are several factors that dictate where infiltration trenches can be used. These include, but are not limited to, soil type and seasonal high water table. These factors are directly related to site selection and design requirements.

Infiltration trenches utilized in cold climates may limit the effectiveness and performance of the system. Issues include winter maintenance activities as well as the potential for system failure due to frost. However, with proper design and maintenance these systems can be effective in cold climates. By keeping the trench surface free of compacted snow and ice, and by ensuring that part of the trench is constructed below the frost line, the performance of the trench during cold weather will be greatly improved (U.S. EPA, 1999c). Infiltration systems are poorly suited for use in areas where it is necessary to apply sand or other deicing agents to the pavement surface. Sand may begin to clog the system, whereas other deicing agents may migrate into the ground water.

Infiltration trenches are an option in medium- to high-density residential, commercial, and institutional areas. The areas selected for the system must have natural occurring soils (no fill sites) with permeable subsoil to provide for infiltration and a water table well below the trench bottom to prevent ground water contamination.

Infiltration of storm water into the underlying soil material is not recommended to treat runoff from designated storm water hotspots due to the potential for ground water contamination. Infiltration trenches should not be used for industrial and manufacturing sites where there is a high concentration of soluble pollutants, pesticides, fertilizers, and heavy metals. Storm water hotspots include areas such as gas/fueling stations, truck stops, vehicle service and maintenance areas, vehicle and equipment washing/steam cleaning facilities, auto recycling facilities, loading and unloading facilities, commercial storage areas, outdoor container storage areas, public works storage areas, commercial nurseries, marinas, hazardous material generators, and industrial rooftops because these areas are frequently subject to the high risk of ground water contamination.

Although efficient as a treatment system for a number of common pollutants, infiltration trenches are not well suited as a pollutant treatment measure in wellhead protection areas or as a measure to treat runoff from storm water hotspots due to possible ground water contamination. Pretreatment that targets specific pollutants may address some of these issues provided the soils below the trench are adequate for the treatment of pollutants. In karst areas, this measure may not be suitable due to potential ground water contamination and the concern of sinkhole formation. Their use in karst areas should only be considered with adequate geotechnical assessment by qualified individuals. Installation of these systems may also be limited due to local requirements or ordinances.

Performance

Efficient performance of infiltration trenches is directly related to site characteristics and proper trench design, installation, and maintenance. Sites with appropriate infiltration rates, limited bedrock, and a ground water table well below the trench will offer the best performance. Regular monitoring and maintenance to prevent clogging of the stone reservoir is critical to ensure performance. Table 1 summarizes performance data for an infiltration trench. To improve overall effectiveness, these systems can be installed as part of a treatment train to target specific pollutants. It is expected that the removal rate for nitrates, chlorides, and soluble metals will be lower, especially in sandy soils (Schueler, 1987).

Table 1: Pollutants Removed Through Infiltration Trenches

Pollutant	Percent Removed
Sediment	90
Phosphorous	60
Nitrogen	60
Metals	90
Bacteria	90
Organics	90
Biochemical Oxygen Demand	70 – 80

Source: Schueler, 1992

Design Specifications

Siting, design, installation, and maintenance of infiltration trenches are critical if they are to function properly and efficiently. Therefore, the trench, and especially the storm water component, should be designed by a professional proficient in hydrology and storm water design.

The decision to use an infiltration trench should include evaluating the site characteristics and incorporating basic elements into the design including, but not limited to, pretreatment, treatment, conveyance, and landscaping.

Pretreatment

Common concerns with the design and performance of infiltration trenches relate to trench clogging and filtering capacity. Pretreatment should be considered, and is recommended, where organic matter, oil and grease, sediment, or other potential ground water contaminants are expected in the runoff. Storm water management measures such as filter strips, grass channels, oil grit separators, and sediment trapping measures are a few options that should be installed to pretreat runoff

Adjacent areas that drain to an infiltration trench should be stabilized and/or designed so that runoff from an adjacent area will not convey sediment to the infiltration trench.

Treatment

A stone reservoir is a key element of an infiltration trench. The reservoir can either be at grade or below grade. At grade systems collect runoff from sheet flow and an underground system receives the runoff through pipes or other types of conveyances. The reservoir should be designed and sized to attenuate and treat a small storm water runoff event (typically 0.5 inch to 1.5 inches). Storage capacity must be designed around the amount of air/pore space in the reservoir since this is the only area where water can be stored.

Conveyance

Infiltration trenches will require some method of conveying storm water runoff to the treatment system. During construction of the overall system it is critical that all conveyance systems and land area above the infiltration system are stabilized with appropriate nonerosive cover. Vegetation is the preferred stabilization method as it will also provide additional pollutant removal.

Infiltration systems should be designed to treat small storms. The initial runoff from a storm event or first flush will typically carry the majority of the pollutants. Runoff that is in excess of the amount to be treated should bypass the infiltration trench and be diverted to a secondary storm water management device or to a stable outlet.

Landscaping

Preventing sediment from clogging the infiltration trench is critical if the system is to function properly. Therefore, it is important to develop and implement a landscaping plan that will ensure that the contributing drainage area is stabilized. This is especially true during active construction, but is also applicable for post construction activities. Unstable, non-vegetated slopes exposed during construction can contribute excessive amounts of sediment to a newly installed trench. ***It is strongly recommended that infiltration trenches be installed during post construction phases after the site has been stabilized.***

The siting and design of an infiltration trench requires evaluation of several key elements such as, but not limited to, soil type, infiltration rate, depth to a limiting layer (e.g., bedrock, a seasonal high water table), slope length and gradient, construction materials, and installation methods.

Siting

Infiltration trenches are poorly suited for use in naturally occurring seasonal high water table soils. For optimal performance, locate systems on deep, well drained, permeable soils.

These systems are not suitable for wellhead protection areas. Their use in areas with karst geology should also be limited without adequate geotechnical assessment by qualified individuals. System placement and design may also be subject to local requirements or ordinances.

The slope of the drainage area above the infiltration trench will influence the velocity of runoff and the overall design of the system. The slope below the infiltration trench should be assessed to minimize slope failure and seepage (see Table 2).

In-depth site assessment is required to determine the applicability of an infiltration trench system. Perform field tests to verify depth to seasonal high water table, depth to bedrock, and soil limitations, including infiltration capabilities. Soils should be homogeneous and should not have any compacted layers or fill.

Table 2 contains site characteristics that should be considered and evaluated when siting and designing an infiltration trench.

Table 2: Site Characteristic Specifications for Infiltration Trench Installation

Site Characteristics	Specification
Drainage area	≤ 5 acres optimum
Slope of site	< 5% up slope; ≤ 20% down slope[1]
Soil type	Undisturbed, minimally compacted (no fill)
Infiltration rate	> 0.5 inches/hour but < 3.0 inches/hour or clay content less than 20% and a silt/clay content of less than 40% and be in U.S. Department of Agriculture Natural Resources Conservation Service hydrologic groups A or B
Water table	≥ 3 feet below bottom of trench[2]
Distance from water wells (private) (public)	Recommended: ≥ 100 feet from trench[2] ≥ 1000 feet from trench[2]
Distance from structures	≥ 100 feet from trench[3]
Distance to bedrock	> 3 feet below trench bottom[2]

Sources: U.S. EPA, 1999c; Georgia Stormwater Management Manual, 2001; Minnesota Pollution Control Agency, Protecting Water Quality in Urban Areas, 1989

[1] Slope ranges may need to be adjusted based on local site conditions including soil properties and geology.

[2] State rules or local ordinances may require greater distances.

[3] Local building codes may dictate setback requirements.

General Design Considerations

The slope of the area that drains to the infiltration trench should be shaped to allow runoff to be evenly distributed in sheet flow as it enters the trench. Concentrated flows may be accommodated through design modification of the infiltration trench system.

The design depth of the trench can range from two feet to ten feet. The most commonly used depth is eight feet (Schueler, 1987).

Trenches that are broader and shallower reduce the risk of clogging by dispersing the runoff to be treated over a larger surface area. Trench widths are typically less than 25 feet (Georgia Stormwater Management Manual, 2001).

The bottom slope of the trench should be relatively flat across its width and length to distribute the flow, provide uniform infiltration, increase the efficiency for infiltration into the underlying soil, and reduce the risk of clogging.

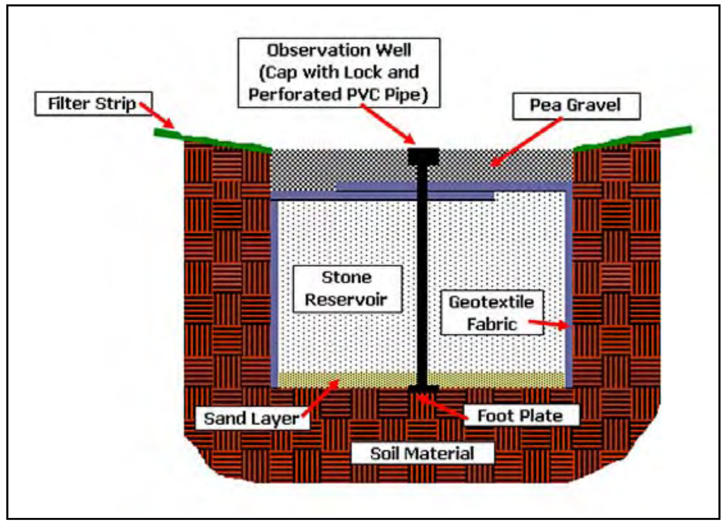
Retention time of runoff in the stone reservoir will influence the pollutant removal efficiency. The system should be designed to maximize the pollutant removal efficiency (see Table 3). Infiltration trenches can be designed to provide temporary storage of storm water. However, the system should be designed to dewater between storm events.

Trenches should always be designed with an overflow conveyance system as a precaution to safely convey runoff if the design storage capacity is exceeded. The overflow should be directed to a stable downstream area. When the system is designed off-line, the design storm should be directed to the trench for treatment, and flows that exceed the design storm should be routed through a conveyance to a secondary storm water management measure or to a stable outlet.

A basic trench design utilizes a stone reservoir to store runoff and promote infiltration. It is recommended that the design be modified by using pea gravel in the upper six to twelve inches of the trench. The addition of the pea gravel will improve sediment filtering and maximize the efficiency of pollutant removal. The pea gravel can be easily removed should the trench require maintenance or become clogged. The upper layers of the system can be modified to include a layer of organic peat or loam. This addition may enhance the removal of metals and nutrients through adsorption (U.S. EPA, 1999c).

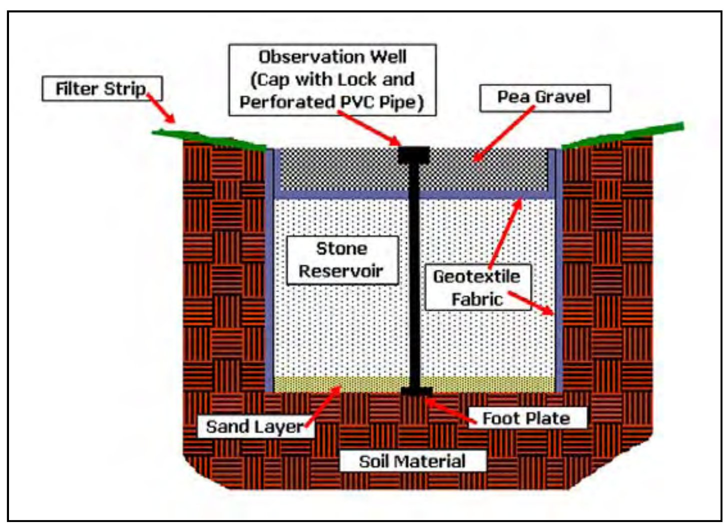
The sidewalls of the trench should be lined with an appropriate geotextile fabric that prevents soil from moving or piping into the stone reservoir. The geotextile fabric should have a greater permeability than the surrounding soil. The installation of the geotextile fabric should also be installed over the stone reservoir to increase pollutant removal, but more importantly to prevent sediment or solids from passing into the stone reservoir thereby reducing the need for frequent maintenance of the stone reservoir.

Figure 2: Infiltration Trench



There are several options for installation of the geotextile over the top of the stone reservoir. The first option is to extend the geotextile to within six to twelve inches from the soil surface, leaving additional fabric that can be folded over the stone reservoir before backfilling with pea gravel (see Figure 2). The fabric should overlap itself a minimum of twelve inches. The second option (see Figure 3) is to extend the geotextile fabric to the surface of the trench. A second layer of geotextile is then placed over the stone reservoir at a depth of six to twelve inches and extended to the top of the trench. The depth of this layer corresponds with the six to twelve inch area that is to be backfilled with pea gravel. This layer of geotextile will need to be maintained more frequently and is installed separate from the fabric lining the sidewalls to allow for easier maintenance and replacement if necessary.

Figure 3: Infiltration Trench



The lower portion of the trench is not lined with geotextile fabric. The bottom of the trench is backfilled with clean, washed sand (See Table 3). The sand will reduce the potential for compaction of the trench bottom when backfilling with the stone and serve as an additional medium for treatment.

Following are additional recommendations and design specifications (Table 3) that should be considered and evaluated when designing and installing an infiltration trench.

Table 3: Trench Characteristics

Trench Characteristic	Requirement
Aggregate size	One to three inch, prewashed aggregate; upper one foot can be replaced with pea gravel
Sand layer	12-inch layer spread uniformly over the bottom of the trench
Filter fabric opening size	$\geq$ 30 micrometers non-woven
Filter fabric depth	Upper edge of fabric one foot below trench surface
Drainage time	$\geq$ 6 hours
Observation well	Four to six inch diameter perforated pipe embedded vertically through aggregate with cap and secured foot plate; long trench lengths may require multiple observation wells (minimum 100 foot spacing)
Trench depth	Standard 8 feet; can be calculated based on infiltration rates, aggregate void space, and trench storage characteristics
Trench volume	Calculations based on first one-half inch of runoff per acre of surface area draining to trench

Sources: U.S. EPA, 1999c; Lowdnes, 2000; Schueler, 1987; Georgia Stormwater Management Manual, 2001; Minnesota Pollution Control Agency, Protecting Water Quality in Urban Areas, 1989

Installation

It is best to install infiltration trenches only after the drainage area has been adequately stabilized to reduce the potential for sediments to enter the system and clog it prematurely. Trench installation should follow the design standards and specifications as outlined in the plans. It is important to note that these systems should be designed by qualified individuals and meet all state and local standards and specifications.

- During excavation of the trench, equipment should be selected that will minimize the compaction of the soils adjacent to the excavation. During excavation of the trench, the bottom and sidewalls should be scarified and all large roots trimmed to provide a uniform sidewall.
- Install the geotextile fabric.
- Place the clean, washed sand into the bottom of the trench.
- Place the prewashed stone into the trench.

- Install the protective layer of geotextile fabric over the stone reservoir.
- The top surface of the trench, above the geotextile fabric, is backfilled with pea gravel. As an alternative, the trench can also be covered with permeable topsoil and planted with grass to improve the aesthetics and blend in with the adjacent landscape. It should be noted that the addition of topsoil may freeze during the winter months, reducing the ability of runoff to infiltrate into the trench.

Maintenance

During the first year of installation, observation wells should be monitored after every significant storm event to ensure proper drainage of the trench. This measure can be monitored seasonally after the first year. To monitor the observation well, use a long stick or rod to check for standing water. Standing water in the well may indicate clogging of the trench. Recheck the well following several days of dry weather. It may be necessary to replace the pea gravel, stone in reservoir, and all or part of the geotextile fabric if the trench becomes clogged. Maintenance should also be performed on storm water measures within the drainage area of the trench to ensure sediment and other solids are removed before runoff enters the trench. Regular inspection and maintenance is critical to maintaining proper functioning of infiltration trenches.

Costs

Annual maintenance costs are estimated at five to ten percent of the initial construction costs (Schueler, 1987). Major rehabilitation of the filter fabric and aggregate fill is often required every five to 15 years (U.S. EPA, 1999c).

Additional Information

Internet Keyword Search:
infiltration trench

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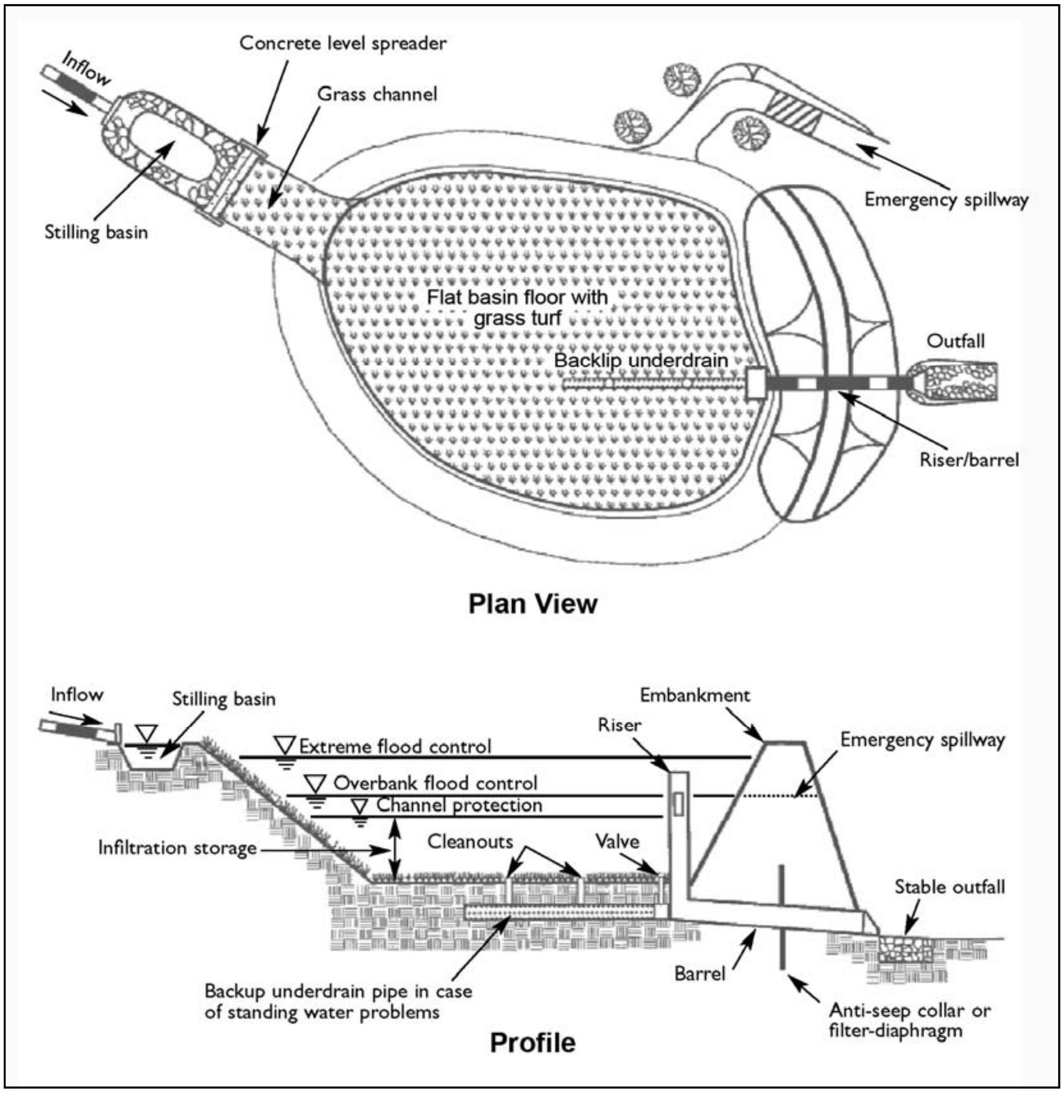
Infiltration Basin

*An **infiltration basin** is a shallow impoundment area constructed in permeable soils to allow infiltration of storm water into the underlying soil. Infiltration basins are efficient at removing nutrients and other pollutants from storm water, providing storage of storm water runoff, and contributing to ground water recharge which helps restore low flows in stream systems.*

Figure 1. Diagram of an Infiltration Basin



Source: Center for Watershed Protection, 1997

Application

There are several factors that dictate where infiltration basins can be used. These include, but are not limited to, soil type and seasonal high water table. These factors are directly related to site selection and design requirements. Infiltration basins are an option in residential, commercial, and institutional areas. Their use is often restricted by concerns for ground water contamination, site feasibility, and the underlying soil material. The areas selected for an infiltration basin should have natural occurring soils. These measures are not typically placed in heavily urbanized areas due to the availability of soils that have not been altered, compacted, or filled.

These measures are typically installed to infiltrate storm water runoff. It is common for these measures to be placed in areas where the infiltration properties of the soil are very high. Soils with high permeability rates will promote infiltration and work well. However, the guidance provided in this manual limits the range of permeability to three inches per hour. This limit is based on water quality benefits. Permeability rates above this limit will provide infiltration, but will reduce the effectiveness for pollutant removal.

Infiltration of storm water into the underlying soil material is not recommended to treat runoff from designated storm water hotspots due to the potential for ground water contamination. Infiltration basins should not be used for industrial and manufacturing sites where there is a high concentration of soluble pollutants, pesticides, fertilizers, and heavy metals. Storm water hotspots include areas such as gas/fueling stations, truck stops, vehicle service and maintenance areas, vehicle and equipment washing/steam cleaning facilities, auto recycling facilities, loading and unloading facilities, commercial storage areas, outdoor container storage areas, public works storage areas, commercial nurseries, marinas, hazardous material generators, and industrial rooftops because these areas are frequently subject to the high risk of ground water contamination.

Although efficient as a treatment system for a number of common pollutants, infiltration basins are not well suited as a pollutant treatment measure in wellhead protection areas or as a measure to treat runoff from storm water hotspots due to possible ground water contamination. Pretreatment that targets specific pollutants may address some of these issues provided the soils within the basin are adequate for the treatment of pollutants. In karst areas, this measure may not be suitable due to potential ground water contamination and the concern of sinkhole formation. Installation of these systems may also be limited due to local requirements or ordinances.

Infiltration basins utilized in cold climates may limit the effectiveness and performance of the system. Issues include winter maintenance activities as well as the potential for system failure due to frost. However, with proper design and maintenance these systems can be effective in cold climates. Infiltration systems are poorly suited for use in areas where it is necessary to apply sand or other deicing agents to the pavement surface. Sand may begin to clog the system, whereas other deicing agents may migrate into the ground water.

Performance

Performance of infiltration basins is directly related to site characteristics and proper design, installation, and maintenance. The efficiency of infiltration basins to filter pollutants from storm water runoff is highly dependent on soil type and the volume of runoff captured. Soils with higher permeability increase infiltration but have a lower capacity for pollutant removal than soils with higher clay content. Regular monitoring and maintenance to prevent clogging of the basin is also critical to ensure performance. To improve overall effectiveness, these systems can be installed as part of a treatment train to target specific pollutants. Table 1 summarizes performance data for an infiltration basin.

Table 1: Pollutants Removed by Infiltration Basins

Pollutant	Percent Removed*
Sediment	74-90
Phosphorous	50-70
Nitrogen	45-60
Trace Metals	75-90
Bacteria	75-90

Source: Schueler, 1987

*Efficiency of pollutant removal depends on the volume of runoff from the first flush captured in the infiltration basin. The larger the volume captured, the more efficient the pollutant removal.

Design Specifications

Siting, design, installation, and maintenance of infiltration basins are critical if they are to function properly and efficiently. Therefore, the basin, and especially the storm water component, should be designed by a professional proficient in hydrology and storm water design.

Information in this section was assembled and adapted from a variety of sources including the U.S. Environmental Protection Agency, Post Construction Storm Water Management in New Development and Redevelopment, *Infiltration Basins* (2002j); Wisconsin Department of Natural Resources, *Wisconsin Storm Wa-*

*ter Manua*l (2000); Metropolitan Council Environmental Services, *Minnesota Urban Small Sites Best Management Practices Manual* (2001); and Minnesota Pollution Control Agency, *Protecting Water Quality in Urban Areas* (1989).

The decision to use an infiltration basin should include evaluating the site characteristics and incorporating basic elements into the design including, but not limited to, pretreatment, treatment, conveyance, and landscaping.

Common concerns with the design and performance of infiltration basins are related to clogging and filtering capacity. Infiltration basins are not sediment control measures. The basin should be designed with appropriate pretreatment measures to trap sediments. Pretreatment should be considered, and is recommended, where organic matter, oil and grease, sediment, or other potential ground water contaminants are expected in the runoff. Storm water management measures such as filter strips, grass channels, oil grit separators, and sediment trapping measures are a few options that should be installed to treat runoff before it is directed to the basin.

Adjacent areas that drain to an infiltration basin should be stabilized and/or designed so that runoff from an adjacent area will not convey sediment to the infiltration basin.

Siting

The siting and design of an infiltration basin requires evaluation and analysis of several key elements such as, but not limited to, soil type, infiltration rate, depth to a limiting layer (e.g., bedrock, a seasonal high water table), slope length and gradient, construction materials, and installation methods. Perform field tests to verify depth to seasonal high water table, depth to bedrock, and soil limitations, including infiltration capabilities. Soils should be homogeneous and should not have any compacted layers or fill material.

Infiltration basins are poorly suited for use in naturally occurring seasonal high water table soils. For optimal performance, locate systems on deep, well drained, soils.

Following are site characteristics and criteria (Table 2) that should be considered and evaluated when siting and designing an infiltration basin.

Table 2: Soil and Site Specifications

Characteristics	Specification
Drainage area	10 acres or less; larger drainage areas may be accommodated based on site and design modification
Infiltration rate of soil	0.5 to 3 inches/hour or clay content less than 20% and silt/clay content of less than 40% and be in the U.S. Department of Agriculture Natural Resources Conservation Service hydrologic group A or B
Depth to bedrock	$\geq$ 3 feet below basin floor[1]
Distance from water wells (private) (public)	Recommended: $\geq$ 150 feet[1] $\geq$ 1200 feet[1]
Water table	Bottom of the basin $\geq$ 3 feet above the seasonal high water table depth
Setback from building, roads, structures, etc.	Local building codes may dictate setbacks.

Source: U.S. EPA, 2002j; Wisconsin DNR, Storm Water Manual, 2000

[1]State rules or local ordinances may require greater distances.

General Design Considerations

Following are additional guidelines and design specifications that should be considered and evaluated when designing and installing an infiltration basin.

Infiltration basins should be designed to treat only small storm events with an emphasis on water quality. The initial runoff from a storm event will typically carry the majority of the pollutants. The first .5 to 1.5 inches of a storm event are typical standards. Local governmental entities will often specify these parameters in ordinances. Infiltration basins should be designed as off-line storm water quality measures. The runoff generated from storms should be directed to the basin for treatment, and flows that exceed the design storm should be routed through a conveyance to a secondary storm water management measure or to a stable outlet.

Basins should be designed to retain runoff and permit infiltration from the desired design storm and to safely pass through, or preferably, bypass flows up to the level produced by the 24-hour, 100-year storm. Basins should always have an emergency spillway to safely convey larger storm events and protect the integrity of the structure.

Calculate the required storage volume from infiltration rates and the desired infiltration time. The majority, if not all infiltration, will occur through the bottom of the basin. It is recommended that the side slopes of the basin are not factored in this determination. This volume is relatively small. Designs should be based on careful evaluation and field testing. Testing and site conditions can be inconsistent; the designer should always allow for a safety factor in calculating the infiltration capability of the soils within the basin.

Typical depths for infiltration basins are three to twelve feet, with the maximum depth based on the infiltration properties of the soils. Shallow basins with large surface areas are more effective than basins that are deep. The basin should be large enough that aerobic conditions are maintained. The basin should have a completely flat bottom and have a length to width ratio of at least 3:1.

Retention time within the basin will influence the pollutant removal efficiency. A minimum drainage time of six hours is recommended for satisfactory pollutant removal (Schueler, 1987; Wisconsin DNR, Storm Water Manual, 2000). The basin may also be designed to provide temporary storage, however the basin should be designed to dewater completely between storm events.

Storm water runoff should be conveyed through the treatment basin in a safe manner that minimizes erosion. Erosion and the deposition of sediment in the treatment area will do little for the performance of this measure. To promote uniform dispersion of storm water runoff and to prevent channeling, the system should be designed with a grass filter strip, level spreader, or other system to promote sheet flow into the basin area.

The basin bottom and side slopes should be seeded to a fast growing permanent seed species. Deep rooted vegetation will increase infiltration. The species selected should be hardy and tolerant of both drought and wet conditions. A thick stand of vegetative cover will promote infiltration and provide stability to prevent erosion. The underlying soil, organic matter, and a grass cover with a sufficient root system will help to decompose and trap pollutants.

The side slopes of the basin should be no steeper than 3:1. Side slopes of 4:1 are preferred due to ease of maintenance.

Part of the system design also includes provisions for maintenance. The designer should provide a stable access point for equipment that will be utilized for maintenance. The basin should also be designed with an under drain if it becomes clogged.

Installation

It is best to install infiltration basins only after the drainage area has been adequately stabilized to reduce the potential for sediments to enter the system and clog it prematurely. Installation should follow the design standards and specifications as outlined in the plans. It is important to note that these systems should be designed by qualified individuals and meet all state and local standards and specifications. Following are guidelines that should be observed during installation of the basin.

Preventing sediment from clogging the infiltration basin is critical if the system is to function properly. Therefore, it is important to develop and implement a landscaping plan that will ensure that the contributing drainage area is stabilized. This is especially true during active construction, but is also applicable for post construction activities. Unstable, nonvegetated slopes exposed during construction can contribute excessive amounts of sediment to a newly installed basin. It is strongly recommended that the infiltration basin be installed during post construction phases after the site has been stabilized.

- Every effort should be made to direct surface runoff away from the basin until the structure and drainage area have been stabilized.
- Basins installed during construction or prior to final stabilization of the drainage area should not be excavated to the design depth. The excavation should be within one to two feet above the final grade. During excavation, equipment should be selected that will minimize the compaction of the soils. Upon stabilization of the drainage area final excavation of the basin can be completed and the basin stabilized.
- If the system is built during the construction phase it is not advisable to utilize the basin as a sediment control measure. The best alternative is to install appropriate erosion and sediment control measures within the drainage area to reduce sediment loading to the basin. If this is not practical or successful, the basin will require maintenance.
- Upon reaching final grade, the basin floor should be tilled to a depth of at least six inches to provide aeration. The addition and incorporation of compost will also aid in infiltration and root growth.
- Construction traffic should also be restricted from the basin.

Maintenance

Maintenance of these measures is high and critical to performance. Appropriate steps must be taken to monitor and observe the operation of an infiltration basin. Poor maintenance will generally result in poor performance and high failure rates. Following are several maintenance tips and a suggested maintenance schedule (see Table 3) for infiltration basins.

- The basin should be evaluated to assess performance. As a general rule, standing water should not remain in the basin for more than two to three days. If the infiltration rates exceed three days, the system may be failing. If there is an indication of failure an assessment of the system should be made by a professional and where appropriate corrective action initiated. Mosquitoes may also become problematic where water does not infiltrate and ponds.
- Sediment accumulation in the basin will require periodic maintenance. This maintenance activity should be completed as needed based on accumulation rates. Remove sediment from the basin under dry conditions and restore original cross section. This activity should be performed with machinery that will minimize the compaction of the soils.
- The infiltration capability of the basin will decrease over time. Periodic tilling and replanting will help restore infiltration rates.
- Mowing is a standard maintenance requirement for basins. The grass should be maintained at a height of at least three inches. The grass should be mowed when the surface of the basin is dry. This will avoid potential problems with compaction and rutting of the basin floor. Mowing under wet conditions may also cause the grass to mat.
- Fertilization may be necessary to maintain healthy vegetation. It is recommended that the application be based on a soil test and applied at the appropriate rate. The use of low phosphorus and slow release fertilizers should also be considered.
- The basin should not be used for parking or as a recreational facility.

Table 3: Summary of Infiltration Basin Maintenance Schedule

Time Schedule	Maintenance Activities
First six months: – Monthly – Following major rainfall events Subsequent: – Semiannually (minimum) – Based on past performance – Following major rainfall events	• Assess operation/infiltration capability (drains according to design).
Annual activities	• Dethatch and scarify the bottom of the basin to ensure infiltration. • Remove accumulated sediment.
As needed	• Stabilize banks and inflow/outflow areas. • Remove and dispose of trash and debris. • Mow the basin to maintain vegetative cover.
Annually/semiannually	• Inspect for: ▪ Erosion. ▪ Sediment accumulation. ▪ Condition of vegetation. ▪ Condition of inlets and outlet.

Source: Minnesota Pollution Control Agency, 1989; Wisconsin DNR, Storm Water Manual, 2000; U.S. EPA, 2002j

Costs

Infiltration basins provide a medium-priced means of storm water filtering. Basin design, site preparation and basin construction will be the largest portion of costs, with maintenance estimated at five to ten percent of original construction costs (U.S. EPA, 2002).

Additional Information

Internet Keyword Search:
infiltration basin

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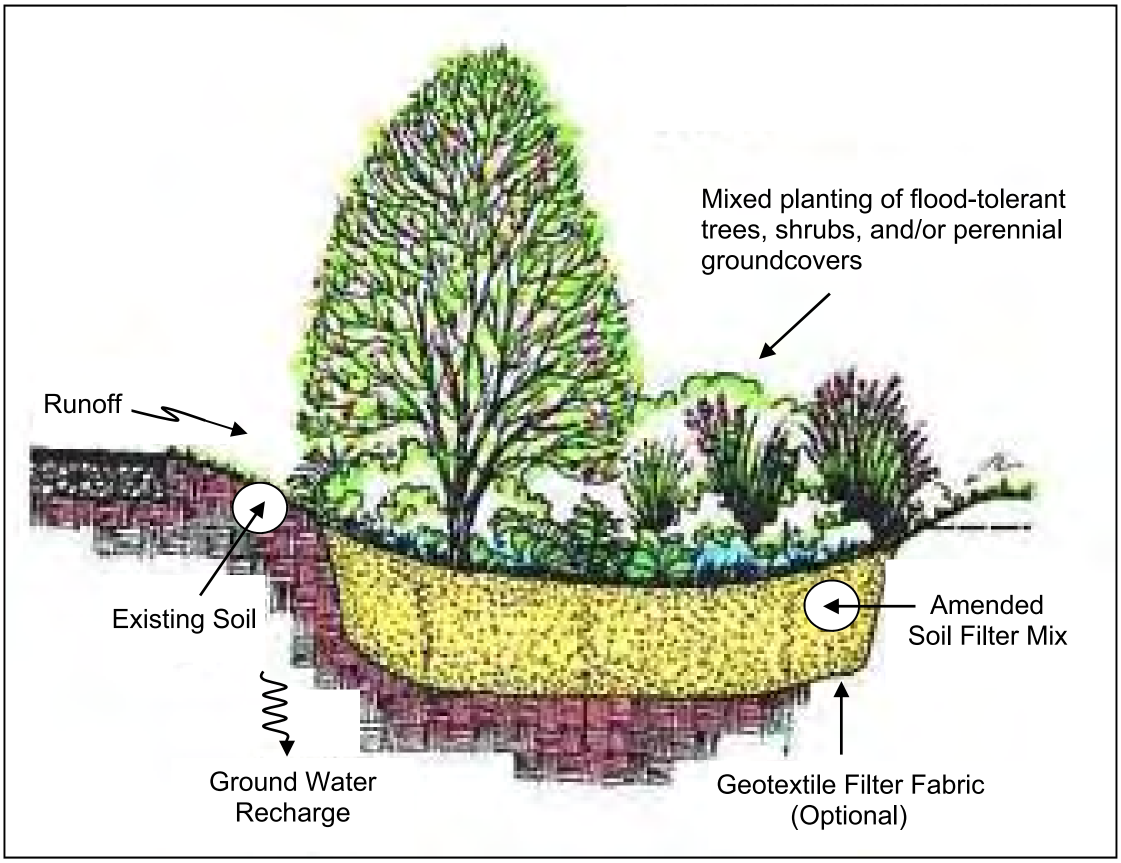
Bioretention Systems

***Bioretention systems** are shallow, landscaped depressions that utilize both soils and plants to remove pollutants from storm water runoff. Storm water runoff enters the system as sheet flow. Runoff collected in the bioretention system either infiltrates into the sand and/or gravel substrate and subsurface soil material or it ponds on the surface of the bioretention system. Some bioretention systems incorporate subsurface drainage in the substrate to allow for the removal of the treated storm water runoff. Bioretention systems are typically designed to allow bypass flow of large storm events.*

Each component of a bioretention system is designed to remove pollutants. This is accomplished through adsorption, filtration, plant uptake, microbial activity, decomposition, sedimentation, and volatilization. Figure 1 displays some of the common components of a typical bioretention system.

Figure 1: Bioretention Cell Profile



Source: Prince George's County, Maryland, Department of Environmental Resources, 2002

Application

Bioretention systems are designed to treat storm water runoff from impervious surfaces. Bioretention systems can be easily incorporated into the design of several filtration and infiltration storm water management systems. They are commonly used in parking lot islands, median strips, and drainage swales. Bioretention systems are not suited to storm water hotspots if infiltration is part of the treatment. To overcome this limitation, the system can be modified with an impermeable liner and subsurface drainage. It is important to ensure that the contributing drainage area is stabilized to lower the impact of sediment loading in the bioretention system treatment area. Following is a list of advantages and disadvantages that should be considered when evaluating whether or not to use a bioretention system (Metropolitan Council Environmental Services, 2001, Minnesota Urban Small Sites Best Management Practices Manual; Georgia Stormwater Management Manual, 2001).

Advantages

- Layout is flexible and aesthetically pleasing due to the incorporation of a variety of plants.
- Reduces volume of runoff from the drainage area.
- Effective at removing fine sediment, trace metals, nutrients, bacteria, and organics.
- Ideally suited to most impervious areas and can be easily adapted to many geologic and climatic environments.
- Reduces downstream flooding and protects channel integrity.
- Provides ground water recharge and base flow in local streams.
- Can be used as a storm water retrofit (modification of landscape or resurfacing a parking lot).

Disadvantages

- Not suitable for treatment of storm water runoff from large drainage areas.
- Clogging may be a problem, especially with high sediment loads.
- Occupies about five percent of the area draining into the system.
- Construction cost can be relatively high compared to other storm water management measures.
- Incorporating bioretention into a parking lot may reduce the availability of parking spaces.

- Not recommended for areas that contain mature trees because measure maintenance may result in damage to the trees and their rooting system.

The following table describes the role that various bioretention system components play in removing pollutants from storm water runoff.

Table 1: The Function of Components in a Bioretention System

Treatment Area	Function	Pollutants Removed
Pretreatment Buffer	Decreases runoff velocity and filters particulates from the runoff.	Solids fall out of suspension.
Sand/Gravel Substrate	Spreads flow evenly throughout length of system.	Provides aerobic condition. Sand substrate provides final treatment of pollutants.
Ponding Area	Temporary storage location for runoff prior to evaporation, plant uptake or infiltration.	Solids fall out of suspension.
Organic Layer or Mulch Layer	Retains moisture in plant zone, filters pollutants and provides an environment for microorganisms.	Filters out finer sediments. Provides some reduction of hydrocarbons, nitrogen, and other organic materials.
Planting Soil	Soil medium (clay) provides an adsorption site.	Adsorption site for hydrocarbons, metals, and nutrients.
Plants	Reduces potential for erosion and promotes uptake of pollutants.	Nutrients and organic pollutants.

Source: Adapted from Metropolitan Council Environmental Services, 2001, Minnesota Urban Small Sites BMP Manual; Georgia Stormwater Management Manual, 2001; Center for Watershed Protection, 1996

Design Specifications

Siting, design, installation, and maintenance of bioretention systems are critical if they are to function properly and efficiently. Therefore bioretention systems should be designed by a professional proficient in hydrology and storm water design.

Following is a list of general guidelines that should be considered in the siting and design of a bioretention system. Table 2 provides additional guidelines that are specific to each of the components of a bioretention system. This information was assembled and adapted from a variety of sources including the *Georgia Stormwater Management Manual* (2001); Metropolitan Council Environmental Services, *Minnesota Urban Small Sites Best Management Practices Manual* (2001); and the Center for Watershed Protection, *Design of Stormwater Filtering Systems* (1996, December). The Center for Watershed Protection document listed above provides in-depth procedures to aid in the design of bioretention systems.

Figure 2: Landscaped Bioretention

Source: Indiana Department of Natural Resources, Lake Michigan Coastal Program

- The drainage area should not exceed five acres. Ideal drainage area is one-quarter acre to no greater than two acres, otherwise the system tends to become clogged with sediment. Multiple bioretention areas may be required for large drainage areas.
- The size of the bioretention area should be five percent to ten percent of the impervious surfaces within the drainage area. The recommended minimum

dimensions for a bioretention area are 10 feet wide by 20 feet long. Any system wider than 20 feet should be at least twice as long to evenly distribute the flow.

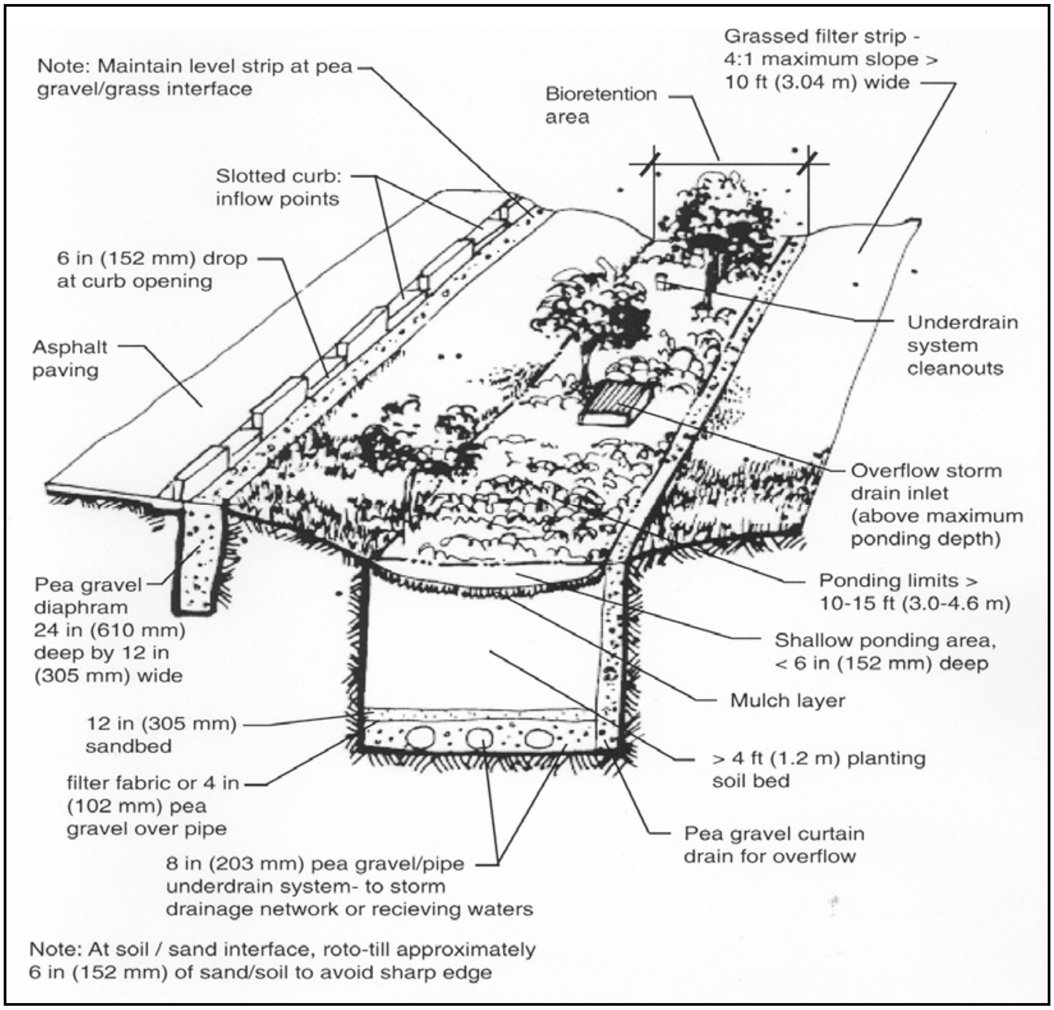
- A ponding depth of six to nine inches is recommended. This depth is adequate for storage and prevents water from standing for an excessive amount of time.
- A bioretention system is engineered with specific media, and soil properties are usually not applicable unless the system is designed for infiltration, thereby allowing runoff to infiltrate into the undisturbed, underlying native subsoil (see the Infiltration Trench section on page 79).
- Slopes should be five percent or flatter.
- The bottom of the bioretention area should be three feet or more above the seasonal high water table to minimize the potential for ground water contamination. To accommodate higher water tables the designer may choose to utilize subsurface drainage.
- Bioretention areas intended for treatment of storm water runoff from parking lots or use as a snow storage area should contain salt-tolerant, non-woody plant species.
- Construction of bioretention systems is most cost efficient and environmentally friendly in sites that are already planned for excavation or landscape grading.

Table 2: Design Criteria for Bioretention Systems

Component	Design Criteria
Pretreatment Area	Filter strips remove suspended sediments from runoff, decreasing sediment load by 25 to 30 percent. This reduces clogging of the system.
Sand/Gravel Substrate	Aeration and drainage for planting bed is provided by a 12 to 20-inch deep sand and/or gravel bed.
Organic Mulch Area	Protects the soil from erosion and retains moisture for plants. • Place two to three inches of mulch after trees and shrubs are planted. Mulch depths greater than three inches interfere with the cycling of gases between the soil and atmosphere. • Use shredded hardwood mulch or chips. • Age mulch at least six months before applying.
Planting Soil Bed	Provides water and nutrients for plants. Specific requirements are: • Clay content between 10 to 25 percent. • Infiltration rate greater than one-half inch per hour. • pH of the soil between 5.5 and 6.5. • One and one-half to three percent organic content. • Maximum of 500 parts per million concentration of soluble salts. • Minimum soil bed depth of four feet; adjust depth to plant variety. • Soil placed in lifts of 12 to 18 inches; loosely compacted.
Under-drain (optional)	An under-drain is a perforated pipe installed at the bottom of the sand bed that collects and removes filtered runoff and directs it to a storm drain system.
Overflow Structure	Incorporate to safely direct flow from large storms to the storm drainage system.
Plants	• Vegetation should predominantly be understory trees, shrub layers, and herbaceous ground cover. • Use at least three different species of each category planted. • The shrub-to-tree ratio is two or three to one. • Trees should be spaced 12 feet apart and shrubs should be spaced eight feet apart.

Source: Georgia Stormwater Management Manual, 2001; Metropolitan Council Environmental Services, Minnesota Urban Small Sites BMP Manual, 2001; Center for Watershed Protection, Design of Stormwater Filtering Systems, 1996, December

Figure 2: Design of a Bioretention System



Source: Center for Watershed Protection

Table 3 shows laboratory and field results regarding the removal of pollutants in bioretention systems.

Table 3: Pollutant Removal Rates (Laboratory and Estimated Values)

Pollutant	Removal Rate
Total Phosphorus	70% – 83%
Metals (Cu, Zn, Pb)	93% – 98%
Total Kjeldahl Nitrogen (TKN)	68% – 80%
Total Suspended Solids	90%
Organics	90%
Bacteria	90%

Source: U.S. EPA

Maintenance

Bioretention systems require regular inspection and maintenance to ensure the system is functioning properly. The frequency interval for inspection and maintenance is much greater in the initial stages of establishing a bioretention system. As vegetation becomes established the inspection and maintenance interval can be extended.

Landscaping and maintenance are usually not any more intensive than traditional landscaping. Therefore, landscaping contractors can perform most maintenance activities.

Table 4: Maintenance Activities in Bioretention Areas

Maintenance Activity	Frequency
Water plants	• As necessary initially. • As needed afterwards during dry periods.
Mulch replacement	• As needed. • Add mulch once per year. • Replace entire area once every two to three years.
Treat diseased trees and shrubs	• As needed. • All should be inspected twice per year for evaluation.
Pruning and weeding to maintain appearance	• As needed.
Inspect pretreatment area and repair eroded areas	• Monthly (initially). • Semiannually.
Planting soils	• Annually test soil pH. If pH is < 5.2, apply an alkaline product (e.g., limestone) one to two times per year to counteract soil acidity. If pH is 7.0 – 8.0, apply iron sulfate and sulfur to reduce pH.
Inspect for sediment accumulation	• Semiannually inspect inflow points for deposition and possible clogging. • Remove sediment. • Clogged systems may be exhibited by excessive ponding. Core aeration or cultivating unvegetated areas may alleviate this issue.
Remove litter and debris	• Monthly. • As needed.
Soil replacement	• When levels of pollutants reach toxic levels that decrease effectiveness of the system.

Source: Adapted from Metropolitan Council Environmental Services, Minnesota Urban Small Sites BMP Manual, 2001; Georgia Stormwater Management Manual, 2001; Center for Watershed Protection, 2001 Fact Sheet

Costs

The cost of constructing bioretention systems is only a little higher than the cost to landscape a new development. Costs are considerably higher to retrofit a site. This increase in costs includes demolition of any pre-existing structures and the placement of suitable soil material for the establishment of vegetation. Operation and maintenance costs for bioretention systems are similar to typical landscaping costs.

Additional Information

Internet Keyword Search:
bioretention ponds, bioretention, biofiltration systems, infiltration systems, storm water filtration

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SETTLING & FLOCCULATION MEASURES

Settling and flocculation measures are typically storm water management measures that have been modified to allow for the settling or flocculation of suspended solids and pollutants that may be attached to the solids. Most of the measures listed in this section of the manual can be effective at reducing peak discharges and flooding, but are relatively ineffective at removing water soluble pollutants. The removal of soluble pollutants may be achieved by selecting or incorporating natural systems, such as storm water wetlands, into the overall design of the measure. Measures in this category include but are not limited to dry ponds, wet ponds, and subsurface detention structures. Sediment forebays and storm water wetlands have also been included in this section as they can achieve multiple objectives, including pollutant removal through uptake by vegetation. These systems can also be utilized as a pretreatment or secondary treatment measure with dry ponds, wet ponds, and subsurface detention.

The design of settling and flocculation measures can be complex and generally require detailed site investigation, including an assessment of potential pollutants and the application of sound engineering principles. A professional knowledgeable of storm water management and water quality principles and experienced in design should be consulted when using these measures.

Dry Extended Detention Basins

Dry extended detention *and* ***dry detention basins*** *are constructed basins that collect, temporarily hold, and gradually release excess storm water from storm events. Detention is achieved through the use of an outlet control structure that regulates the rate of storm water outflow. Unlike wet ponds, dry detention basins are designed to drain completely between storm events, thereby attenuating peak flows associated with storm events. Dry extended detention basins are particularly effective at reducing downstream streambank erosion related to increased peak discharge associated with urbanization. Dry basins are usually designed to drain in less than 24 hours. Dry basins are limited in ability to retain sediment. Sediments that settle out are subject to resuspension. Dry extended detention basins are designed with a minimum retention time of 24 hours. Through careful design, dry extended detention basins can be effective at removing urban pollutants. Treatment is primarily achieved by the sedimentation process where suspended particles settle to the bottom of the basin. Based on this information, dry extended detention basins are the preferred option when choosing between an extended basin and a conventional dry basin.*

Application

Dry extended detention basins, when carefully planned and constructed, are applicable in a wide variety of situations. The flexibility of basin design makes this measure one of the more versatile storm water management measures.

Dry extended detention basins should not be considered the final solution for pollutant removal. These structures have limited effectiveness for pollutant removal. The pollutants that are associated with runoff from the drainage area should be evaluated and considered when selecting and designing a measure. This will be particularly critical if the drainage area includes storm water hotspots. Therefore, consideration should be given to pretreatment storm water quality measures or alternative measures should be selected in place of dry detention that will meet the objectives for pollutant removal.

Following are several benefits and limitations associated with the use of extended dry detention basins (Georgia Stormwater Management Manual, 2001; Connecticut Stormwater Quality Manual, 2004; U.S. Environmental Protection Agency, 2002d).

Benefits

- Minimal benefit at removing suspended sediment (extended basins only).
- Acts to mitigate flood events associated with increased runoff from urban areas.
- Can serve as recreational areas during dry periods.
- Can provide wildlife habitat.

Limitations

- Require a relatively large land area that is directly proportional to the size of the watershed.
- May cause thermal impacts to receiving waters.
- Generally require a drainage area of 10 acres or more to avoid an excessively small outlet structure susceptible to clogging.
- Not intended as a water quality measure. Ineffective in the removal of low-density pollutants such as gas and oil and pollutants not readily absorbed to sediment particles.

Dry extended detention basins can also be an effective retrofit application for storm water management in older developed areas. Many older developments include some form of flood control or water detention basin that can be easily converted to the design criteria used in dry extended detention basins by adding a water control structure and doing limited excavation.

Design Specifications

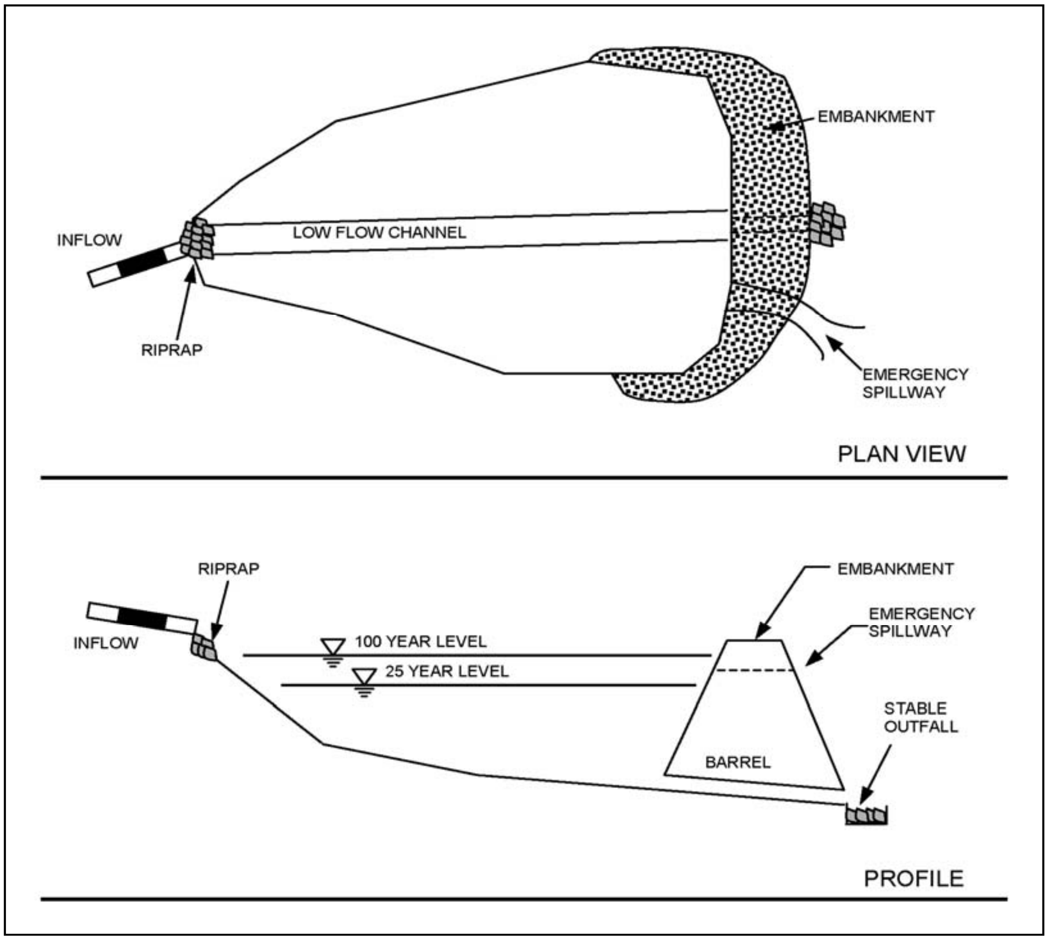
Proper design, siting, installation, and maintenance of dry detention and extended dry detention basins are critical if they are to function properly and efficiently. Therefore, these measures should be designed by a professional proficient in hydrology and storm water design.

The design of detention basins to address storm water quantity is usually dictated by local storm water ordinances. These ordinances will typically require these structures to be designed for the post-development peak flow to meet the pre-development level.

Dry detention basins (see Figure 1) are usually designed to dewater in less than a 24-hour period. Dry detention basins should be designed with adequate pretreatment measures or designed as an extended basin. A dry extended detention basin (see Figure 2) is designed to completely drain in 24 hours or more. The design of a dry extended detention basin may still require storm water quality measures for pretreatment above the basin, but also incorporates several design modifications that may address water quality objectives. These design specifications and modifications are listed below.

When designing a dry extended detention basin consideration must be given to small storm events that will typically contain the majority of pollutants throughout the year. If the small storms are not considered in the design, the runoff may not be adequately treated (Minnesota Pollution Control Board, 1989). An extended basin can be designed with additional storage or micropools in the lower stages of the pond to treat runoff from smaller storms while the upper stages provide capacity for larger storm events.

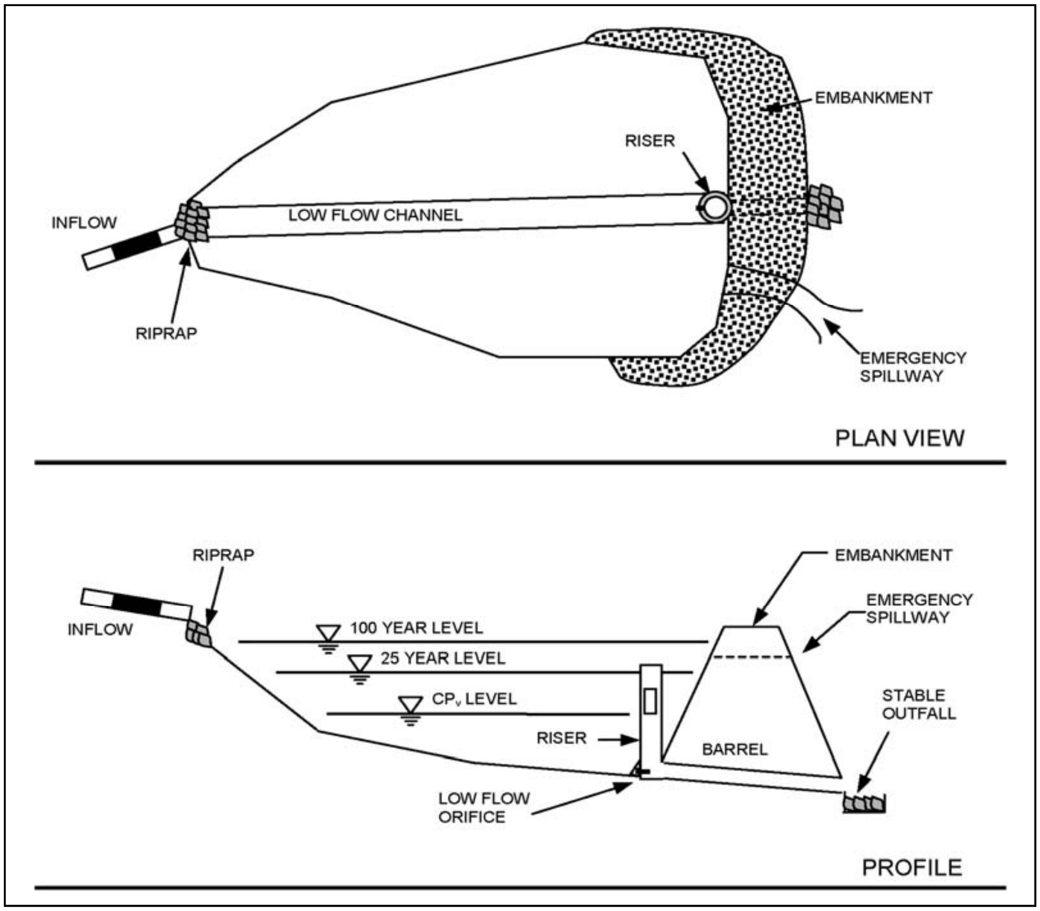
Figure 1: Dry Detention Basin



Source: Georgia Stormwater Management Manual, 2001

Dry detention basins are intended to provide peak flow reduction of the 25-year storm (Q_{p25}) and can be designed to control the 100-year (Q_t) storm event.

Figure 2: Dry Extended Detention Basin



Source: Georgia Stormwater Management Manual, 2001

Dry extended detention basins provide downstream channel protection through extended detention of the channel protection volume (CP_v) and provide peak flow reduction of the 25-year storm (Q_{p25}) and the 100-year (Q_t) storm event.

Low Flow Channels

Low flow channels should be incorporated into the design of dry detention basins to reduce erosion as runoff enters the pond and to route storm events to the outlet, thereby reducing ponding and providing adequate drainage of the basin.

Volume

Volume is generally determined by local requirements or sized to treat 85 percent of the annual runoff volume. Indiana rainfall data can be found in the Indiana Stormwater Drainage Manual published by the Indiana Local Technical Assistance Program [formerly the Highway Extension and Research Project for Indiana Counties and Cities (Burke and Burke, 1995)]. Detailed calculation methodologies are included in this manual as well as rainfall data for various regions within the state.

When designing for the storage of storm water runoff volume, it is important to consider local effects such as soil type and amount of impervious surfaces, and to include compensation for future increases in impervious areas. Extended basins should be sized with a storm water detention time of at least 24 hours, depending on the size of the storm event.

Siting

Extended dry basins should be limited to drainage areas of ten acres or more in order to maintain an orifice opening at the outlet that is sufficiently large to prevent clogging. Basins can be constructed on sites with slopes up to 15 percent, provided the slope within the basin can be made relatively flat to ensure proper design flow. Soils are rarely a limiting factor. Ideally, the basin should be sited on soils with infiltration rates of less than three inches per hour. Sites with highly permeable soils or in a karst landscape may require an impermeable liner or other modification to protect ground water, especially if the basin is being constructed for treatment of runoff from a “hotspot” area. In all cases, the ground water level should remain below the base of the pond at all times to allow the pond to dry out. Site selection should be chosen to maximize flow path length between the inlet and outlet and allow for maximum storm water detention and release capability of the basin (see the pond configuration section of this measure).

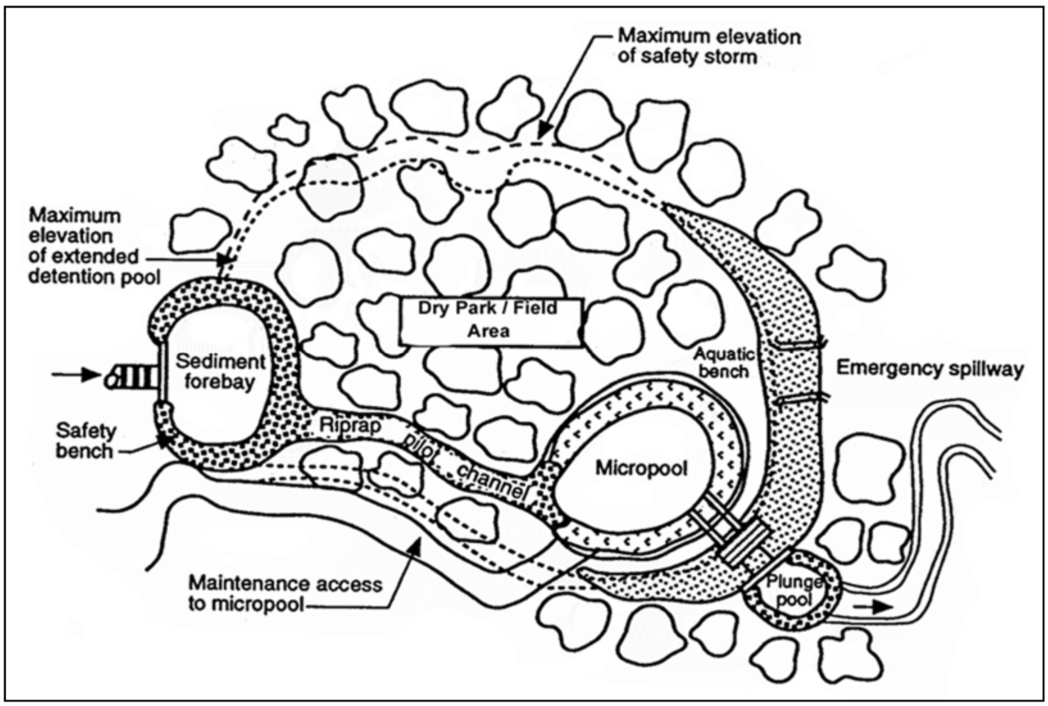
Pond Configuration

- ### Inlet
  Energy dissipation is required at the basin inlet to reduce resuspension of accumulated sediment and to reduce the tendency for short-circuiting. This can be accomplished with the installation of a sediment forebay pond, or other upstream pretreatment measure. A sediment forebay is an inlet structure separated from the rest of the basin. Sediment forebay ponds are designed to capture sediment before it enters the main body of the detention basin (see Figure 3). Sediment forebay ponds are usually separated from the main basin by a wall or berm. Sediment forebay structures act to concentrate sediment in a single area of the basin, making cleaning more efficient and less costly.

- ### Shape and Slope
  Dry extended detention basins should have a shape with a length to width ratio of at least 3:1 in order to maximize retention time and maximize the length of the flow path between the inlet and outlet. In the event that this shape is not feasible, engineered structures (baffles and internal grading) which convey the water through the basin with the desired flow rate and residence time may be incorporated into the basin design.

All basin side slopes should be limited to a ratio of 3:1. The side slopes of vegetated embankments should be designed at 3:1 (horizontal to vertical). Riprap protected embankments should be no steeper than 2:1. A minimum of one foot of freeboard is recommended above the 100-year storm volume. A geotechnical engineer should evaluate slope stability on sites where the embankment berm is in excess of ten feet (Georgia Stormwater Management Manual, 2001). Slopes should be planted immediately with a quick rooting annual as well as long term perennials in order to stabilize slopes and prevent erosion. Basin bottom slopes should be on the order of two percent to achieve complete drainage, but site specific design criteria may be required to establish appropriate grade.

Figure 3: Dry Pond With Sediment Forebay and Micropool



Source: Schueler, 1992

- **Outlet**

  The basin's drawdown time should be regulated by a gate valve, orifice plate, or notched weir. Outlet structures should be designed to allow the controlled release of detained storm water runoff and should include measures to deter clogging by debris (e.g., trash racks, skimmers, etc.). Outlet structures should be designed with stability in mind and should be resistant to frost heaving and failure under saturated conditions. All outlet structures must include a stable nonerosive spillway on their downstream side to prevent scour associated with the discharge from the basin.

  Basins should incorporate an emergency spillway capable of safely passing a minimum of a 100-year flow event efficiently through the basin.

These spillways should be reinforced and capable of withstanding significant flood conditions. Measures should be taken to stabilize an outlet apron on the downstream side of the emergency spillway so as to reduce the risk of berm failure from scour in a high flow situation. A stabilized outlet apron must be located on the downstream side of the emergency spillway to reduce the risk of embankment failure as a result of scour in a high-flow situation.

- **Micropools**

  In much the same way as sediment forebay ponds trap sediment coming into the basin, a similar feature called a micropool can provide additional pollutant removal before water exits the basin. Micropools are relatively shallow, permanent pools or a series of pools. These micropools can be planted with wetland species or include a shelf with wetland species. Micropools are usually constructed at or very near the outlet of the basin and incorporate easy maintenance access into their design (see Figure 3).

Maintenance

Maintenance activities vary between sites. Construction of a sediment forebay pond and micropool limit the amount of work needed to excavate excessive sediment deposits from the dry extended detention basin. Table 1 summarizes maintenance activities and their recommended frequency.

Table 1: Typical Maintenance Schedule for Dry Detention Basins

Activity	Schedule
• Inspect for erosion along pond surfaces.	Two times per year
• Inspect for embankment damage. • Monitor sediment accumulation in the basin, sediment forebay pond, and micropool. • Check operation of inlet and outlet structures and remove accumulated debris.	Annually
• Restore dead or damaged ground cover via sodding or seeding.	As needed (at a minimum of annually)
• Remove sediment from sediment forebay pond and micropool.	As needed (can be as frequent as monthly or as infrequently as biannually)
• Monitor sediment accumulations, and remove when sediment forebay pond or dry detention basin storm water storage volume is reduced 25 percent.	As needed (possibly every 10 years)
• Remove litter and debris from basin inlet and outlet.	Standard monthly maintenance

Source: U.S. EPA, 2002d

Costs

According to the U.S. Environmental Protection Agency (2002d), dry detention basins are the least expensive storm water management measure based on a cost per unit area treated. Construction costs vary considerably depending on whether the basin is a cut or a fill design and other site specific criteria. According to a study by Brown and Schueler (1997) the cost of dry extended detention basins can be roughly estimated by the following equation:

$$C = 12.4V^{0.760}$$

Where: C = Construction, design and permitting cost (dollars)

V = Volume needed for the 10-year storm event (ft^3)

Annual maintenance costs of dry basins are usually estimated at three to five percent of the construction cost (U.S. EPA, 2002d). However, community participation in annual maintenance of the basin during dry periods can greatly reduce these costs. Given the relatively long life of these facilities [(20 years or more) U.S. EPA, 2002d], the initial investment is spread over a relatively long time period.

Additional Information

Internet Keyword Search:
dry pond, detention basin, extended detention pond, retention basin

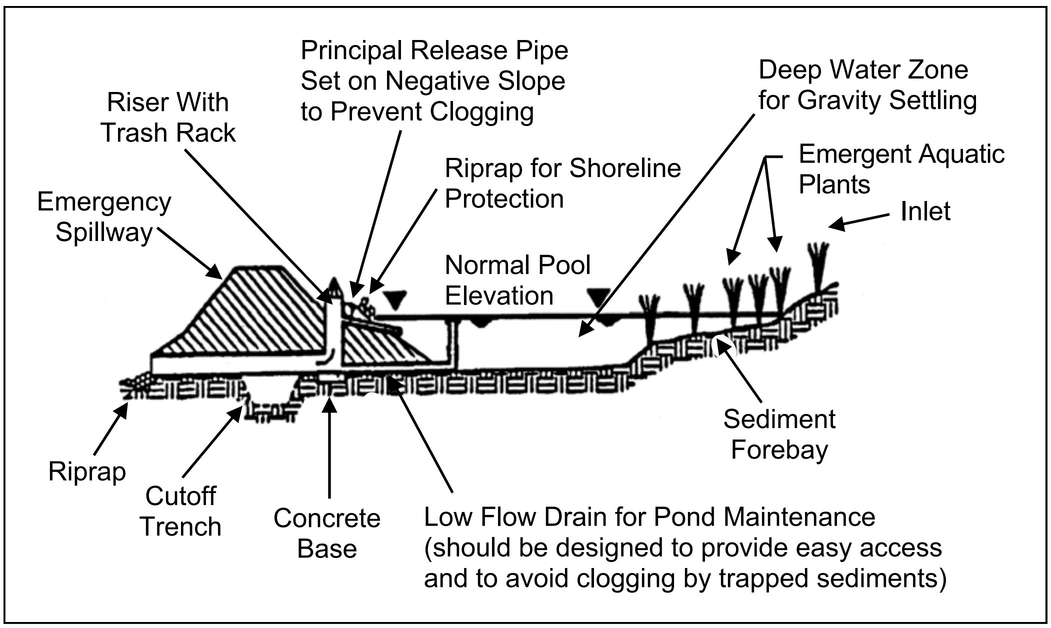
Federal Resource:
U.S. Department of Agriculture Natural Resources Conservation Service manuals

Indiana Resource:
"Stormwater Drainage Manual" published by the Indiana Local Technical Assistance Program [formerly the Highway Extension and Research Project for Indiana Counties and Cities (Burke and Burke, 1995)]

Wet Detention Ponds

***Wet detention ponds**, including storm water ponds, retention ponds, and wet extended detention ponds, are constructed basins that contain a permanent pool of water and treat polluted storm water runoff. The most commonly used wet detention ponds are extended detention ponds. The purpose of a wet detention pond is to detain storm water runoff long enough for contaminated sediments to settle and remain in the pond and allow the water in the pond to be displaced by the next rain event. This sedimentation process removes particulates, organic matter, and metals from the water while nutrients are removed through biological uptake. By capturing and retaining runoff, wet ponds control both storm water quantity and quality. A higher level of pollutant removal and storm water quality can be achieved through the use of wet detention ponds than with many other storm water management measures such as sand filters and dry ponds.*

Figure 1: Typical Layout of a Wet Detention Pond



Source: Maryland Department of the Environment, 1986

Application

Wet detention ponds are suited for use in residential, commercial, and industrial development areas. These ponds have the capability to remove soluble pollutants and are suitable for areas with an expected high level of nutrient inflow.

These measures may be installed in areas where the contributing watershed is associated with a storm water hotspot. However, consideration should be given to a separation between the bottom of the pond and the seasonal high water table. A separation depth of three feet or more is usually sufficient.

Wet detention ponds are suitable for use in karst topography, however there is a potential for ground water contamination or the formation of a sinkhole. Therefore, the design of the pond may require an impermeable liner to address one or more of these issues.

Table 1: Wet Pond Advantages and Disadvantages

Advantages	Disadvantages
• Flood control for downstream areas by providing flood storage above the pool. • Decreased potential for streambank erosion downstream. • Once established, sediment removal from wet detention ponds is generally less frequent as compared to other storm water management measures. • Improved water quality due to pollutant removal of: ▪ Suspended solids ▪ Metals ▪ Soluble pollutants ▪ Nutrients • Pond can be aesthetically pleasing and increase the value of surrounding properties. • Provides wildlife habitat.	• Improper design, siting, or maintenance may result in: ▪ Adverse effects on water quality, ground water, or wetlands. ▪ Release of nutrients and metals from trapped sediments due to stratification and anoxic conditions. • Precautions needed to prevent damage to wetlands during pond construction. • Evaluation for potential of ground water contamination is required. • Potential for thermal impacts downstream (temperature increase). • High maintenance cost.

Source: U.S. EPA, 1999f; Connecticut Stormwater Manual, 2004; Metropolitan Council Environmental Services, 2001, Minnesota Urban Small Sites BMP Manual

Wet detention ponds remain one of the most effective storm water management measures for the removal of pollutants. The range in pollutant removal values is dependent upon the volume of the permanent pool in relation to the contributing watershed, the hydraulic residence times (i.e., the rate at which water moves through the pond), proper design, and proper maintenance of the pond. Sediment forebays or other pretreatment measures will increase the efficiency for pollutant removal. The addition of wetland or marsh areas (i.e., shallow pools with aquatic plantings) can also be incorporated to increase nutrient uptake.

Table 2: Removal Efficiencies From Wet Detention Ponds

Parameter	Percent Removal
Total Suspended Solid	50 – 90
Total Phosphorus	30 – 90
Soluble Nutrients	40 – 80
Lead	70 – 80
Zinc	40 - 50
Biochemical Oxygen Demand or Chemical Oxygen Demand	20 – 40

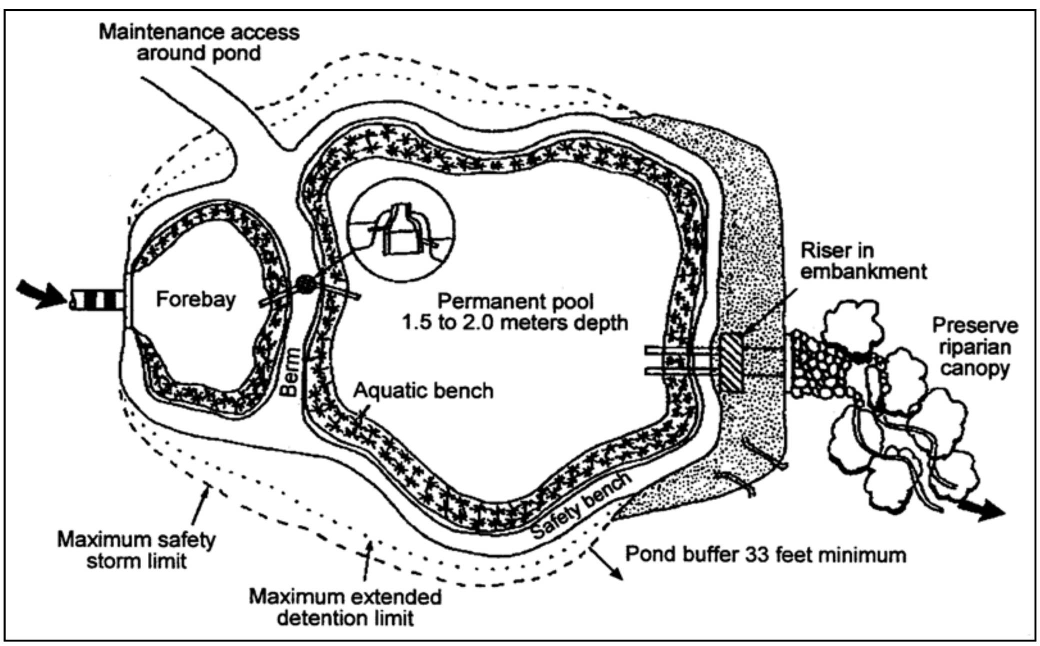
Source: Schueler, 1992

Design Specifications

Proper design, siting, installation, and maintenance of wet detention ponds are critical if they are to function properly and efficiently. Therefore, these measures should be designed by a professional proficient in hydrology and storm water design.

Wet detention pond designs are unique for each site and application. Sites should be chosen based upon their ability to support the environment, their cost effectiveness in a topography that allows the maximum storage at minimum construction costs, etc. There are several general design criteria that influence the design of wet detention ponds (see Figure 2 and Table 3).

Figure 2: Schematic of a Wet Detention Pond



Source: Schueler, 1987

Table 3: General Design Specifications for Wet Detention Ponds

Parameter	Design Criteria
Site Location	• Underlying soils within hydrologic soil groups C and D should be adequate to maintain a permanent pool. • Select site with adequate base-flow to maintain a permanent pool.
Drainage Area	• The contributing drainage area should be adequate to maintain the minimum water level in the permanent pool. Typically, the drainage area will be a minimum of 25 acres. However, this may need to be adjusted based on design and site characteristics.
Storm Water Quantity Requirements	• Design to control post-development peak discharge rates to predevelopment levels. • Design to control multiple types of storm events (e.g., two- and/or 10-year storms) and safely pass the 100-year storm event.
Storm Water Quality Requirements	• Removal efficiency of pollutants depends on the length of time that runoff remains in the pond (i.e., hydraulic residence times). Both sediment and biological uptake increase with longer HRT.
Dimensions of the pond must be calculated to achieve the HRT	• The depth of the permanent pool is typically between three to eight feet. If the pond is too deep, thermal stratification and anoxic conditions may develop. If it is too shallow, trapped sediments could become resuspended. Deeper depths near the outlet may yield cooler temperatures and mitigate downstream thermal impacts.
Pond Design: Volume Ratio	• VB/VR is the ratio of the permanent pool storage to the mean storm runoff. Larger VBs and smaller VRs create increased retention and treatment between storm events, whereas low VB/VR ratios result in poor pollutant removal.
Pond Design: Area Ratio	• A/As is the ratio of contributing drainage area to the permanent pool surface area. Area ratios of less than 100 have better pollutant removal efficiencies.
Pond Design: Length-to-Width Ratio	• 3:1 length-to-width ratio is used when water quality is of concern. High ratios will decrease the potential of short-circuiting and will increase sedimentation within the permanent pool. Also, features such as baffles can create longer routes through the pond and increase HRT.
Pond Design: Shoreline Slopes	• Shoreline slopes between 5:1 and 10:1 allow easy access for maintenance. • The side slopes of the permanent pool should be no steeper than 3:1. • Ponds should be wedge-shaped so flow enters the pond and gradually spreads out, thereby minimizing potential of little or no-flow zones. • Ponds should have a bench or ledge below water level to stabilize pond slopes and provide safety.
Pond Design: Embankments	• During construction, the embankment should be overfilled by at least five percent to allow for subsidence and settling of the embankment. • Minimize seepage (affects stability of embankments) by adding drains, anti-seepage collars, and core trenches. • Minimum inner slope of 2:1, outer slope 3:1, and stabilized with vegetation or riprap to prevent erosion. • Minimum top width of seven feet to aid in maintenance.

Table 3: General Design Specifications for Wet Detention Ponds (*continued*)

Parameter	Design Criteria
Pond Design: Access	• The layout of the pond should provide access areas to conduct routine and long-term maintenance.
Pond Design: Outlet Control Structure	• Discharge is controlled by a riser and inverted release pipe. Normal flows discharge through the outlet (reinforced concrete or corrugated metal riser and barrel). Risers in or adjacent to the embankment provide easy access for maintenance. • The pond should contain a low-flow drain with an adjustable gate valve allowing for gradual discharge. Recommended drawdown is 24 hours.
Pond Design: Sediment Forebay	• Sediment forebay ponds are small pools (about 10 percent of the volume of the permanent pool) that remove coarse particles from runoff before they reach the permanent pool. They reduce pond maintenance (dredging).
Pond Design: Emergency Spillway	• Emergency spillways are sized to safely convey large flood events. Spillways prevent water levels from overtopping the embankment.
Pond Design: Landscaping	• Landscaping makes the wet pond aesthetically pleasing and enhances pollutant removal. • A vegetated buffer around the pond will protect the banks from erosion and remove pollutants from overland flow.

Source: Adapted from U.S. EPA, 1999f; Georgia Stormwater Management Manual, 2001; Maryland Department of the Environment, 1986

There are several different design variations for wet detention ponds that are adaptable to various sites. Table 4 describes three of the most common design modifications.

Table 4: Alternative Designs for Traditional Wet Detention Ponds

Type of Pond	Description	Characteristics
Wet Extended Detention Pond	Combines the treatment capabilities of dry extended detention basins and wet detention ponds. Water volume is split between the permanent pool and the detention storage. Water is retained during storm events and released into the permanent pool over 12 to 48 hours.	• Similar in pollutant removal efficiency to a wet detention pond and requires less space. • Designed to maintain half the treatment volume of the permanent pool. • Focus on attenuating peak runoff. • Vegetation must withstand both dry and wet periods.
Micropool Extended Detention Pond	Micropools are typically used for peak runoff and utilize a small permanent pool pond near the outlet of the main pond.	• Less pollutant removal than wet detention ponds. • Used where contributing drainage area is small and insufficient to maintain a larger pool area. • Useful for sites with small spaces or a retrofit application.
Multiple Pond Systems	A series of constructed ponds, typically two or more.	• Multiple cells increase flow path length and improve pollutant removal efficiency. • May reduce overall maintenance requirements; more frequent maintenance is performed in the first pool versus the large primary pool. • Requires more land area to treat the same runoff volume as other measures.

Source: U.S. EPA, 2002; Connecticut Stormwater Manual, 2004; Georgia Stormwater Management Manual, 2001

Maintenance

The performance of a wet detention pond is highly dependant on the maintenance of the pond. If the pond is not properly maintained, the ability of the pond to remove pollutants will decrease. There are several types of maintenance activities required for a traditional wet detention pond.

Table 5: Typical Maintenance of Traditional Wet Detention Ponds

Maintenance Activity	Schedule
• If wetland component is present, inspect for invasive vegetation and remove.	Semiannual inspection
• Inspect for damage (e.g., structural integrity of spillway or embankment). • Monitor for sediment accumulation in the wet detention pond and sediment forebay pond.	Annual inspection and/ or after storm events
• Repair undercut or eroded areas.	As needed
• Clear debris from inlet and outlet structures and ensure they are operational.	Monthly
• Manage and harvest wetland plants.	Annual (if needed)
• Remove sediment from the forebay.	Every 5 to 7 years
• Remove sediment from the permanent pool when pool volumes are reduced or the pond is eutrophic. (Sediments are usually suitable for landfill disposal.)	Every 20 to 25 years

Source: Adapted from Watershed Management Institute, 1997

Costs

Wet detention ponds are typically expensive to construct. However, the ponds are long lasting [greater than 20 years (U.S. EPA, 2002f)] and have relatively low maintenance costs. The annual cost of maintenance is three to five percent of the construction cost (Schueler, 1992). The expense for constructing a wet detention pond depends on the size of the facility.

Table 6: Construction, Design and Permitting Costs

Size of Facility	Costs
1 acre-foot	$45,700
10 acre-foot	$232,000
100 acre-foot	$1,170,000

Source: U.S. EPA, 2002

Additional Information

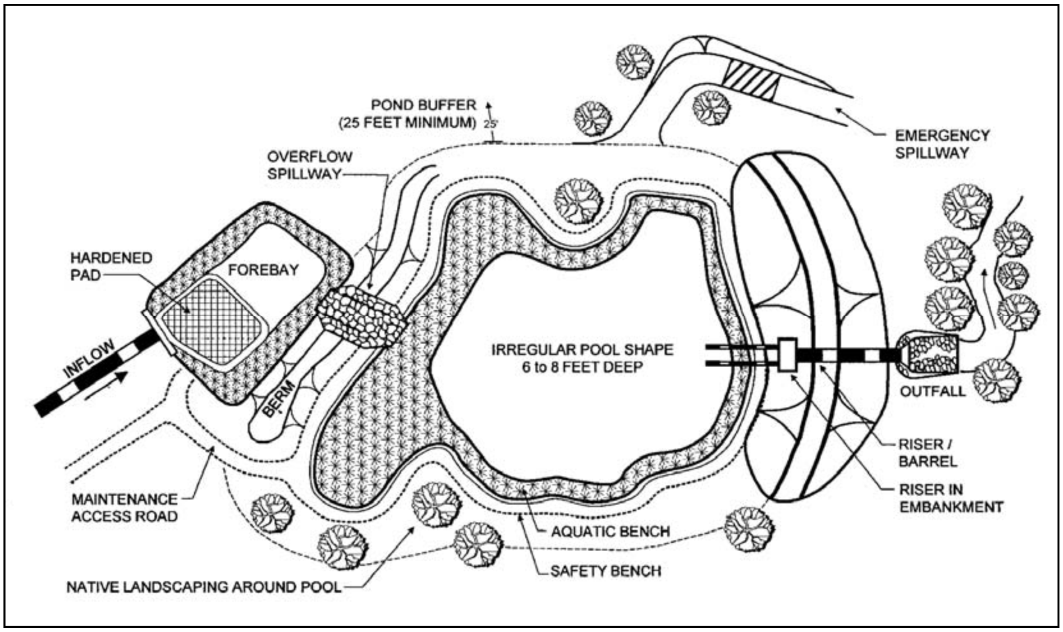
Internet Keyword Search:
wet ponds, detention basin, settling basin, retention pond

Federal Resource:
U.S. Department of Agriculture Natural Resources Conservation Service manuals

Indiana Resource:
"Stormwater Drainage Manual" published by the Indiana Local Technical Assistance Program [formerly the Highway Extension and Research Project for Indiana Counties and Cities (Burke and Burke, 1995)]

Sediment Forebay Ponds

***Sediment forebay ponds** are small structures placed in front of infiltration storm water quality measures and larger structures such as a wet detention ponds, dry extended detention ponds, or constructed wetlands. The purpose of the forebay is to intercept, concentrate, and settle out a majority of the sediment that is coming into the system before it reaches the larger pond or basin. This creates a convenient collection place for sediment cleanout as opposed to performing frequent maintenance on the larger downstream storm water quality measure.*



Source: Center For Watershed Protection, 2002

Application

Sediment forebay ponds, when carefully planned and constructed, are suitable for use in a wide variety of situations. The main function of a sediment forebay is for pretreatment of storm water runoff. Outside of proper design their success rests mainly on the frequency of maintenance and cleanout. Below are some benefits and limitations associated with sediment forebay ponds.

Benefits

- Provides an area to trap sediment that is easily accessible for maintenance.
- Effective at removing suspended sediment and pollutants attached to sediment particles.
- Can prevent some large debris from entering main structure.

Limitations

- Must be inspected and cleaned on a regular basis because of small size.
- Can be an eyesore if not properly maintained.
- Treatment capacity is directly related to the size of the pond, often making space the primary limiting factor.

Sediment forebays can easily be retrofitted to existing basins in older developed areas or areas where changing land use has introduced more sediment to the system.

Design Specifications

Proper design ensures maximum performance of sediment forebay ponds. Siting, design, installation, and maintenance of sediment forebays are critical if they are to perform properly and efficiently. Therefore, sediment forebays should be designed by a professional proficient in hydrology and storm water design. The design incorporates three important values: sizing, site selection, and pond configuration. Paramount to an efficiently designed sediment forebay pond is estimating the correct volume of storm water runoff that can pass through the basin and still remove the majority of sediment. Below are major design feature considerations of sediment forebay ponds.

Siting

Sediment forebay ponds should be positioned upstream of the larger pond or storm water management structure and located in an area with easy access for maintenance equipment. A forebay should be located at each inlet that contributes ten percent or more of the design storm inflow (Georgia Stormwater Management Manual, 2001).

Size

The size of the sediment forebay pond will vary based on the downstream structure. About ten to 25 percent of the surface area of the downstream pond should be devoted to the forebay (Metropolitan Council Environmental Services, 2001, Minnesota Urban Small Sites Best Management Practices Manual). Typical depths associated with a forebay are four to six feet (Georgia Stormwater Management Manual, 2001). The size of the forebay may be enlarged to increase detention of runoff and provide additional treatment.

Shape

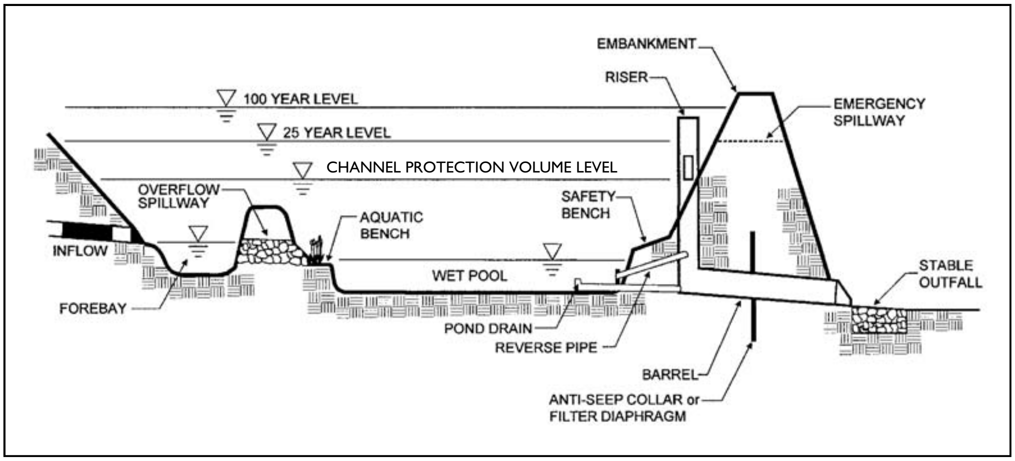
The shape should be long and narrow if possible to facilitate settling of suspended particles. Design to avoid resuspension of previously settled material. Typical length to width ratios are 3:1 to facilitate retention time and removal efficiency.

Separation Berm

A barrier to separate the forebay from the permanent structure should be included as part of the design. The barrier may be constructed of permeable soils or materials such as INDOT CA #8 crushed stone. Other options may include a weir, pipe structure, gabion baskets, riprap, pavers, or other nonerosive materials.

Overflow

The overflow should be able to efficiently pass flows exceeding design specifications; velocities must not be erosive.



Source: Center For Watershed Protection, 2002

Maintenance

Sediment forebay ponds are labor intensive. Depending on the amount of sediment that is present in the system, cleanout of the forebay pond can be as frequent as monthly or as infrequent as biannually. Cleanout should occur when sediment buildup is no more than 50 percent of the storage capacity of the forebay pond. Sediment forebay ponds should be located in areas that provide easy access for equipment to remove accumulated sediment. Disposal of the sediment must be considered and may include hauling and transportation to a separate site.

Costs

Compared with the cost of the larger detention or settling ponds, sediment forebay ponds are a fairly inexpensive preventative solution to the problem of excessive sediment buildup in the larger structures. Cost analysis should consider not only construction but also long-term maintenance including frequent cleanout, hauling and disposal of accumulated sediments.

Additional Information

Internet Keyword Search:
retention ponds, forebay ponds, dry ponds, detention basin

National Resource:
U.S. Department of Agriculture Natural Resources Conservation Service manuals

Indiana Resource:
"Stormwater Drainage Manual" published by the Indiana Local Technical Assistance Program [formerly the Highway Extension and Research Project for Indiana Counties and Cities (Burke and Burke, 1995)]

Constructed Storm Water Wetlands

Source: U.S. Department of Agriculture, Natural Resources Conservation Service

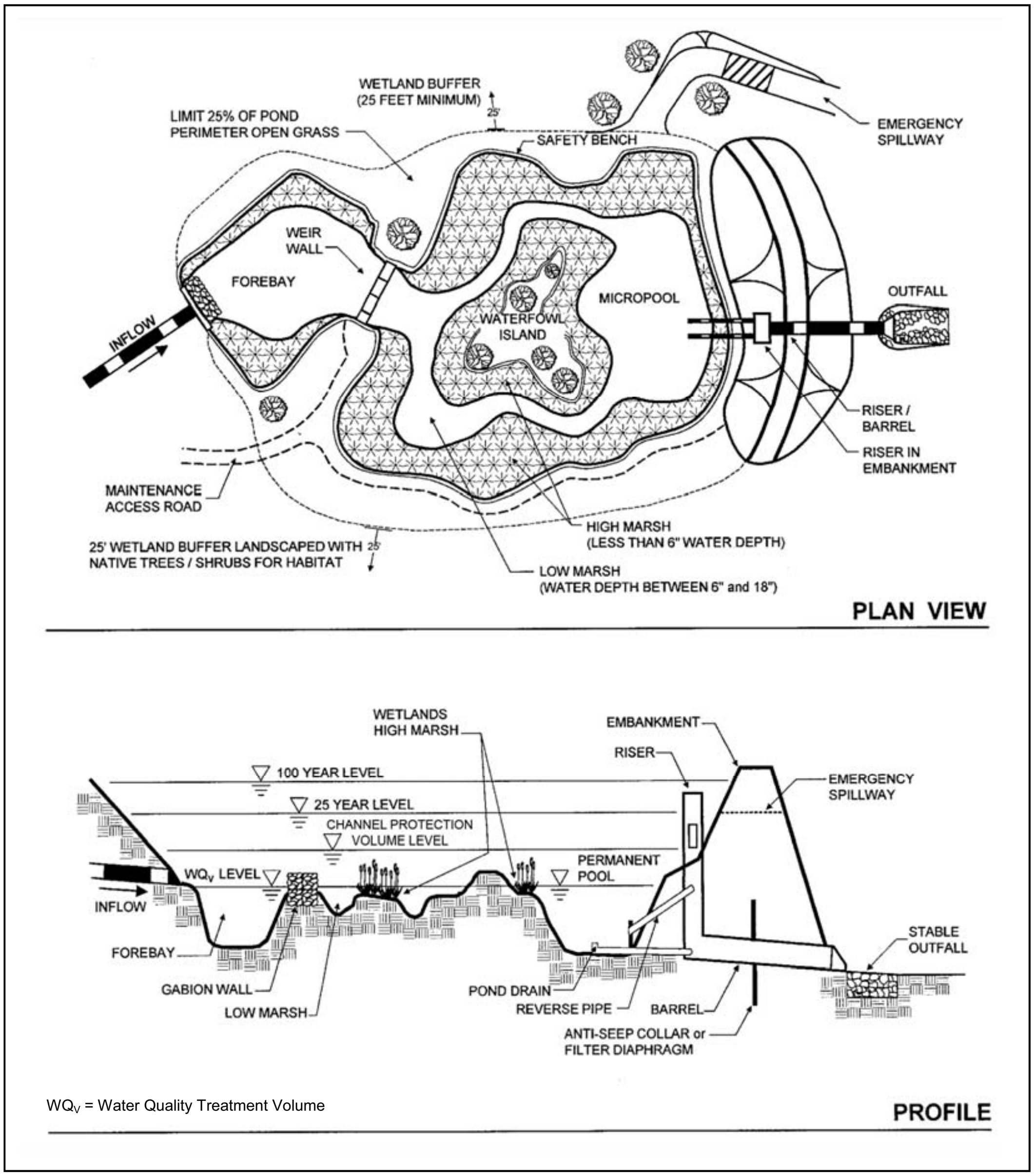
***Constructed storm water wetlands** (also called constructed wetlands) are man-made systems that utilize wetland plantings and permanent pools of varying depths to control the quantity and quality of runoff and to treat urban storm water. Pollutants are removed from storm water runoff flowing through the wetland facility by the settling of pollutants under low-flow conditions and vegetative uptake. Storm water runoff quantity is reduced by evapotranspiration and infiltration. Peak flow is reduced by storage and slow release. Several types of wetlands exist and each has advantages and disadvantages.*

Table 1: Wetland Types

- **Shallow Wetland:** In shallow wetlands, most of the water quality treatment occurs in the shallow marsh depths. One disadvantage to this design is that because the pool is very shallow, a large amount of land is needed to store the water volume (see Figure 1).
- **Extended Detention Shallow Wetland:** The extended detention shallow wetland is similar to a shallow wetland except part of the water treatment occurs as a result of extended detention above the surface of the marsh. This design can treat a greater volume of water in a smaller space than a shallow wetland. Plants which can tolerate wet and dry periods need to be planted in the extended detention area of the wetland (see Figure 2).
- **Pond/Wetland System:** The pond/wetland system has two separate cells: a wet pond and a shallow marsh. The wet pond acts as a sediment trap and reduces runoff velocities prior to storm water entering the wetland. Less land is required for a pond/wetland system than for shallow wetlands (see Figure 3).
- **Pocket Wetland:** Pocket wetlands are intended for smaller drainage areas of five to 10 acres. They typically require excavation down to the water table in order to assure a reliable water source (see Figure 4).

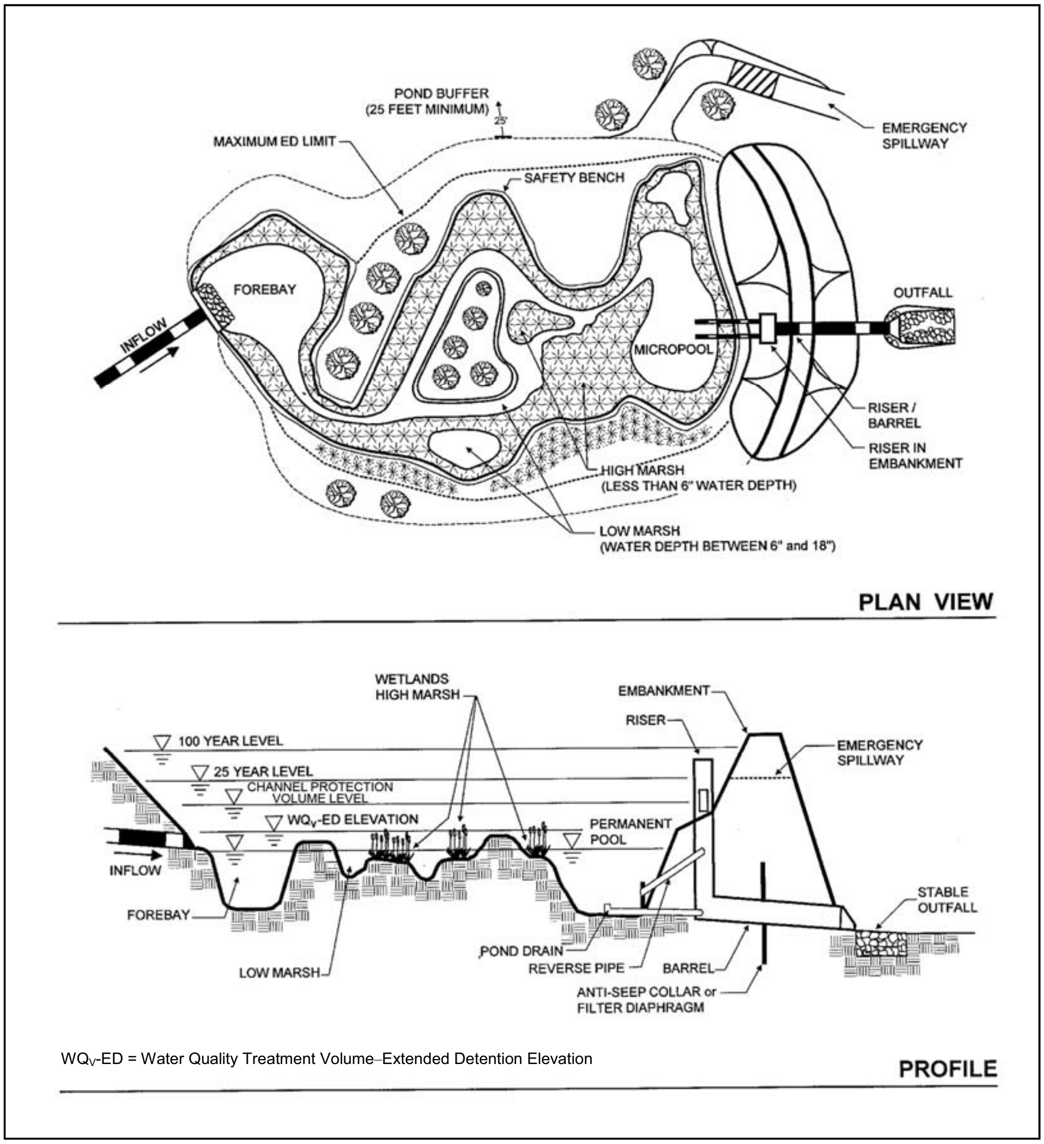
Source: Georgia Stormwater Management Manual, 2001

Figure 1: Shallow Wetland



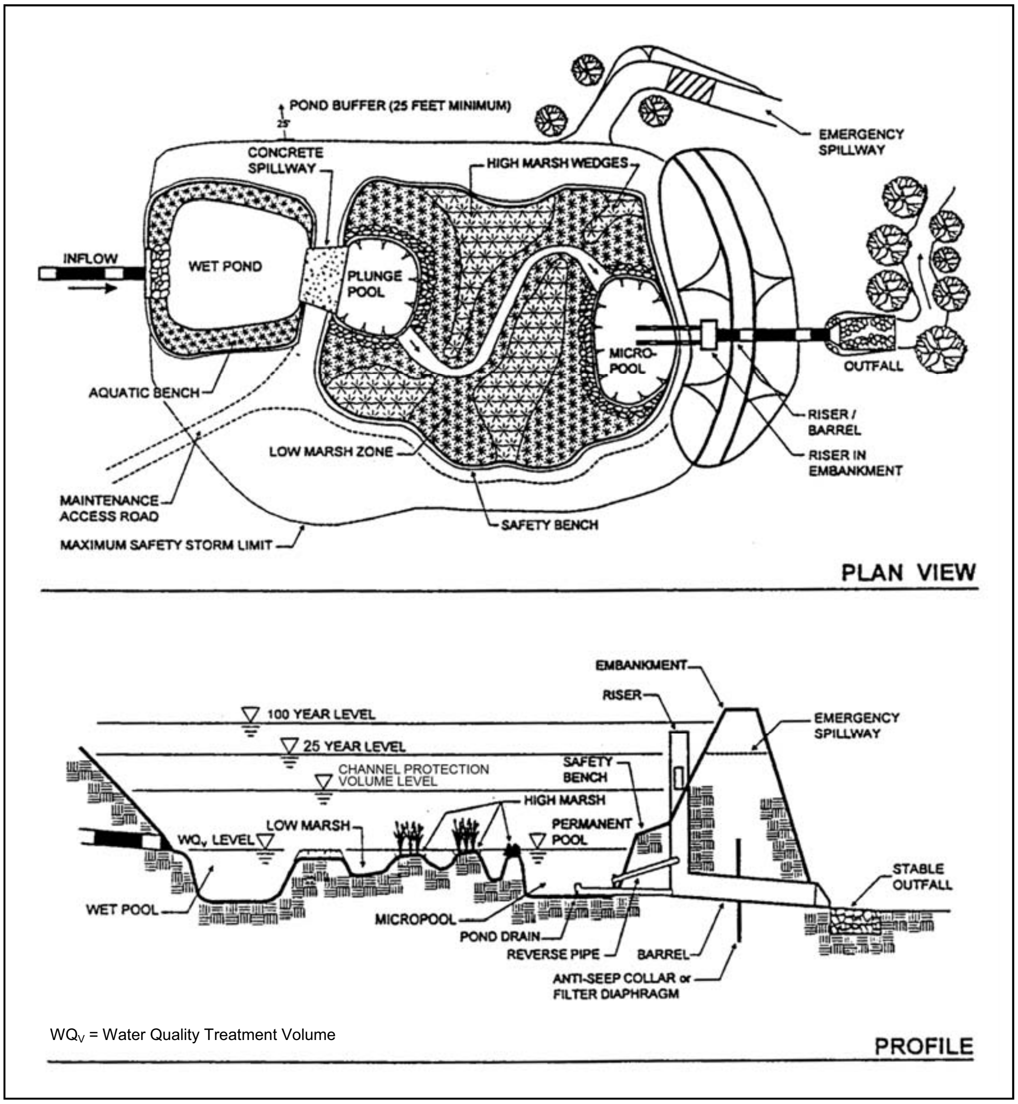
Source: Center for Watershed Protection

Figure 2: Extended Detention Shallow Wetland



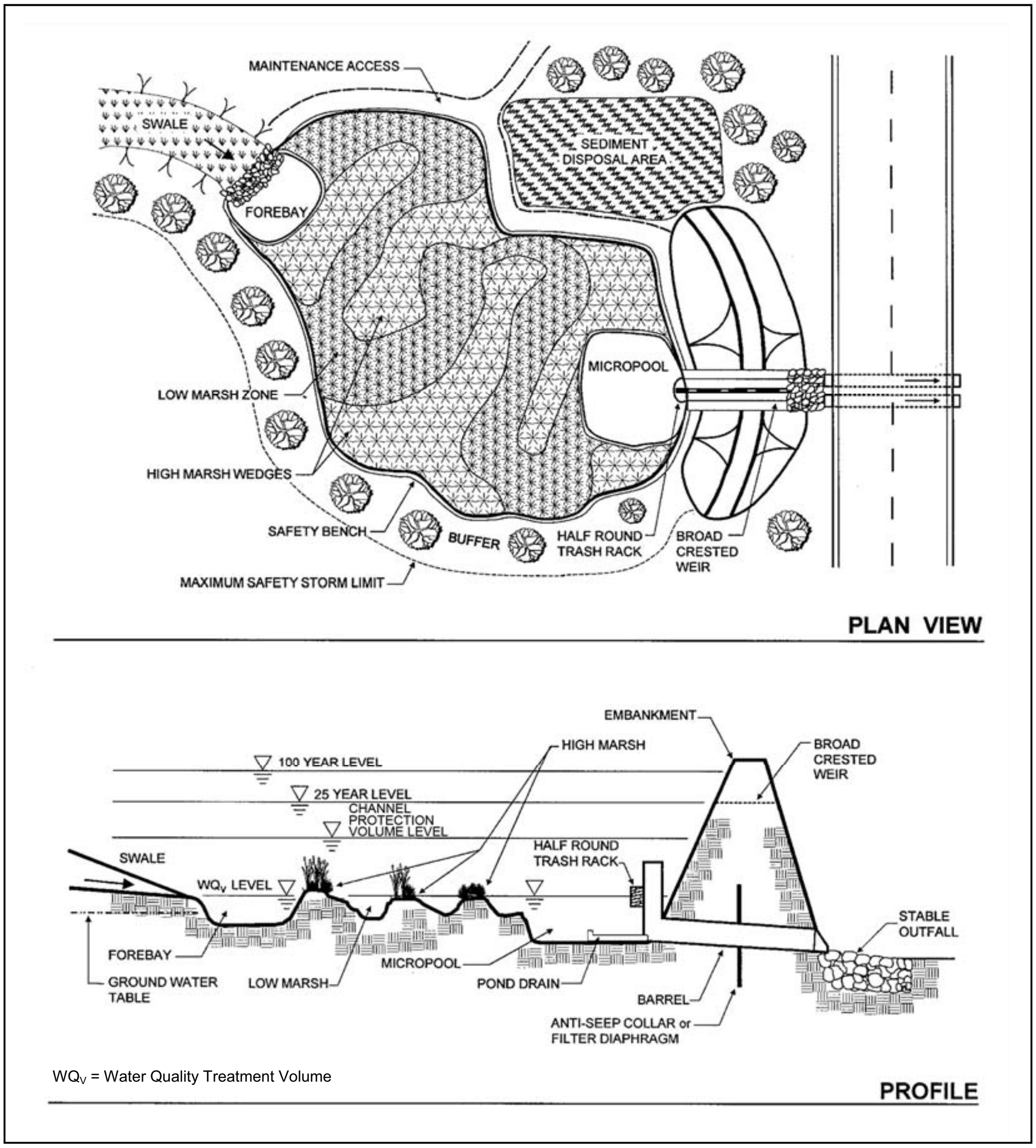
Source: Center for Watershed Protection

Figure 3: Pond/Wetland System



Source: Center for Watershed Protection

Figure 4: Pocket Wetland



Source: Center for Watershed Protection

Application

Storm water wetlands are well suited for a variety of land uses; however, the measure may have limitations in highly urbanized areas.

These measures may be installed in areas where the contributing watershed is associated with a storm water hotspot. However, consideration should be given to a separation between the bottom of the wetland and the seasonal high water table. A separation depth of three feet or more is usually sufficient.

Storm water wetlands are suitable for use in karst topography, however there is a potential for ground water contamination or the formation of a sinkhole. Therefore, the design of the wetland may require an impermeable liner to address one or more of these issues.

Constructed storm water wetlands are designed to maximize the removal of pollutants from storm water runoff. This is accomplished through several processes—microbial breakdown of pollutants, settling and adsorption, retention, and plant uptake. Constructed storm water wetlands temporarily store storm water runoff in shallow pools designed to promote the processes discussed above. They offer many advantages over other storm water attenuation measures.

Table 2: Constructed Storm Water Wetland Advantages and Limitations

Advantages	Limitations
• Effective nutrient removal. • Provides wildlife habitat. • Relatively low maintenance costs.	• Require large land area. • Needs continuous base flow, or a base outlet elevation that maintains a minimum water level. • Require minimum drainage area of 10 acres for adequate water source.

Source: Adapted from Metropolitan Council Environmental Services, Urban Small Sites BMP Manual, 2001

The pollutant removal effectiveness of shallow wetlands and pond/wetland systems has been well documented. However, the data available for extended detention and pocket wetlands is limited. Table 3 provides the pollutant removal rates for wetlands as a whole (Center for Watershed Protection, 1997; U.S. EPA, 1999g).

Table 3: Performance of Storm Water Wetlands

Pollutant	Percent Removal Rate
Total Suspended Solids	67
Total Phosphorous	49
Total Nitrogen	28
Organic Carbon	34
Petroleum Hydrocarbons	87
Cadmium	36
Copper	41
Lead	62
Zinc	45
Bacteria	77

Source: Center for Watershed Protection, 1997

Design Specifications

Several criteria need to be taken into consideration when designing a constructed storm water wetland, including drainage area size and soil type. Siting, design, installation, and maintenance of storm water wetlands are critical if they are to function properly and efficiently. Therefore, storm water wetlands, and especially the storm water component, should be designed by a professional proficient in hydrology and storm water design.

Design Criteria

- Minimum contributing drainage area of ten to 25 acres; one to ten acres for pocket wetlands.
- Minimum dry weather flow path ratio of 2:1 to 3:1 (preferred) (length to width) should be provided from inflow to outflow.
- Criteria for sizing wetlands vary from state to state. One recommendation is based on runoff treatment volume. The volume is determined as the quantity of runoff generated by 90 percent of the runoff producing storm (Metropolitan Council of Governments (Schueler), 1992b). The impervious surfaces within the watershed will also influence the runoff volume. The following equations can be used to calculate the treatment volume.

$$Rv = .05 + .009\,(I)$$

Where:
Rv = Runoff Volume
I = Percent (as decimal) of site impervious area

$$Vt = [(RPs)\,(Rv)\,(A)/12]\,(43{,}560)$$

Where:
Vt = Treatment volume (cubic feet)
RPs = Runoff producing storm in inches
A = Contributing drainage area

Source: Metropolitan Council of Governments (Schueler), 1992b

This is only one alternative. Other design options are available from other agencies including, but not limited to, the U.S. Department of Agriculture, Natural Resources Conservation Service.

- Pretreatment of runoff should be provided by incorporating a sediment forebay pond or an equivalent measure upstream of the wetland.
- A site targeted for a storm water wetland must have an adequate watershed and soils to maintain sufficient water levels and vegetation. Permeable soils are not well suited to this measure. Soils within the Natural Resources Conservation Service hydrologic soil groups B, C, and D are usually best suited

to this measure. Typically these hydrologic groups will only exhibit small infiltration losses. Soils with high infiltration rates will require an impermeable synthetic or compacted clay liner to reduce infiltration loss (U.S. EPA, 1999g).

The design guidelines in Table 3 on page 139 have been developed by the Metropolitan Council of Governments (Schueler, 1992) for design of wetland systems.

Maintenance

Proper maintenance is necessary to keep a constructed storm water wetland functioning effectively. Table 4 lists maintenance criteria of constructed storm water wetlands and the interval with which they should be performed. Table 3 also provides several maintenance activities for each wetland type.

Table 4: Maintenance Criteria

Activity	Schedule
• Replace wetland vegetation to maintain 50 percent coverage for wetland plants after second growing season.	One time activity
• Clean and remove debris from inlet and outlet structures. • Mow side slopes.	Frequently (3 to 4 times a year)
• Monitor wetland vegetation and perform replacement plantings as necessary.	Semiannual Inspection (first 3 years)
• Examine stability of the original depth zones and micro-topographical features. • Inspect for invasive vegetation and remove where possible. • Inspect embankment and inlet/outlet structure for damage. Repair as necessary.	Annual Inspection

Source: Georgia Stormwater Management Manual, 2001

Costs

Constructed storm water wetlands have a fairly high initial cost. However, once established, their annual maintenance cost is estimated to be three to five percent of construction cost (U.S. EPA, 2002). Constructed storm water wetlands should be considered in areas where the removal of suspended solids from storm water runoff is desired and space is sufficient to allow construction of a wetland facility.

Table 3: Design Criteria

Design Criteria	Shallow Wetland	Pond/Wetland	Extended Detention Wetland	Pocket Wetland
Wetland/ Watershed Ratio	.02	.01	.01	.01 (target)
Minimum Drainage Area	25 acres	25 acres	10 acres	1-10 acres
Land Consumption	High	Moderate	Moderate	Moderate, but can be shoehorned in landscape
Length to Width Ratio (minimum)	1:1	1:1	1:1	1:1 (target)
Water Balance	Dry weather baseflow normally recommended to maintain water elevations. Ground water not recommended as the primary source of water supply to wetland			Water supply provided by excavation to ground water
Extended Detention	No	No	Yes	No
Allocation of Treatment Volume (pool/wetland/extended detention)	40/60/0	70/30/0	20/30/50	20/80/0
Allocation of Surface Area (deep/low/high)	20/40/40	45/25/30	20/35/45	10/40/50
Cleanout Frequency	2 to 5 years	10 years	2 to 5 years	5 to 10 years
Forebay	Required	No	Required	Optional
Micropool	Required	Required	Required	Optional
Outlet Configuration	Reverse-slope pipe or hooded broad crested weir	same	same	Hooded broad crested weir
Propogation Technique	Mulch or Transplant	Mulch or Transplant	Mulch or Transplant	Volunteer
Buffer (feet)	25 to 50	25 to 50	25 to 50	0 to 25
Pondscaping Plan	Emphasize wildlife habitat wetland microtopography, and buffer	Emphasize wildlife habitat, wetland complexity, and buffer	Emphasize stabilization of extended detention zone; fluctuating water levels impose physiological constraints	Pondscaping plan optional; wildlife suitability and plant diversity low due to small area and low diversity

Source: Adapted from Schueler, 1992; Metropolitan Council Environmental Services, Urban Small Sites BMP Manual, 2001

Additional Information

Internet Keyword Search:
storm water wetland, constructed storm water wetland, constructed wetland
storm water control

Subsurface Detention/Retention

Source: Marion County Soil and Water Conservation District

Subsurface detention systems *are designed to store storm water runoff and release the storm water to a receiving water. Retention systems are designed to provide infiltration, storm water storage, and ground water recharge where it would otherwise be impossible due to extensive impervious surfaces. These systems primarily function to address peak runoff and are not installed as a storm water quality measure, although they may be retrofitted or used as part of a treatment train for this purpose. The lack of open space available for the construction of aboveground structures, such as ponds and wetlands, for mitigating storm water runoff makes subsurface structures a very useful alternative in these constraining situations.*

These systems can be constructed of steel, concrete or high-density polymer. There are two main forms these structures take. The first is a subsurface full or semi-pipe network that may or may not be porous and allow for infiltration. The second is an engineered porous matrix, often constructed of high density polymers that can be designed to permit both detention and infiltration if necessary. Both forms allow for pavement to be placed over the top, or soil if a more natural covering is desired.

Application

These systems are not specifically designed as a storm water quality measure. Pollutant removal is minimal and is usually limited to settling of coarse sediments. Resuspension and discharge of sediments during storm events is also a concern. These measures are often used as part of a treatment train.

SUBSURFACE DETENTION/RETENTION

Underground detention/retention systems are well suited to new development and redevelopment areas. These systems are often selected due to the availability and cost of land. Most systems are installed under parking lots or paved surfaces. They can also be installed under grassed areas. The overall benefit of these systems is to make land available for other uses that would have normally been used for a retention/detention pond. Typical locations of this measure are associated with commercial, industrial, and residential development. Systems designed to infiltrate runoff into the underlying soil are not well suited to storm water hotspots or wellhead protection areas. Pretreatment of storm water runoff that targets the pollutants in the drainage area and those associated with the land use may be used to mitigate the surface water and ground water resource concerns associated with this measure

Subsurface detention/retention structures have advantages and disadvantages that should be considered when selecting these measures.

Advantages	Disadvantages
• Durable	• No water quality benefit
• Provide a level of safety over ponds	• Requires sediment control device
• Provide ground water recharge	• Can be problematic to fix
• Capture and store storm water runoff	• More expensive (requires excavation)
• Little restriction on use of space above ground	• Systems designed to infiltrate may contribute to ground water contamination

Source: U.S. EPA, 2002c

In addition to maintaining local infiltration of storm water runoff, perhaps the most obvious reason for the choice of these structures over traditional aboveground structures is because they allow for dual use of the land they occupy. Parking lots or greenspace can be easily maintained above the detention system, thereby eliminating economic loss from land used for classic aboveground structures such as detention ponds.

There are few differences between the choice of an underground pipe system versus a geotextile grid. Probably the largest single difference is the amount of void ratio available, or storage, for a given unit area of soil. Because of its design the geotextile grid will allow for a larger amount of storage than the classic pipe system. In turn, allowing controlled outflow from geotextile grids is difficult, as they are designed primarily for infiltration into porous soils below the structure.

Design Specifications

Siting, design, installation, and maintenance of subsurface detention/retention systems are critical if they are to function properly and efficiently. Therefore, these systems, and especially the storm water component, should be designed by a professional proficient in hydrology and storm water design. Listed below are design considerations common to both pipe systems and geotextile grids.

- Design size is usually for the 10-year, 24-hour event; bypass mechanisms should be in place to pass excessive or prolonged events.
- Retention systems designed to provide infiltration must consider the soil properties where the system will be installed. They are best suited to well-drained soils with a seasonal water table well below the structure to allow for infiltration. Typical soil infiltration rates should range from .5 to 3.0 inches per hour.
- To achieve a water quality benefit, pretreatment of storm water is required. Storm water may be pretreated by incorporating an oil-grit separator, hydrodynamic separator, grass swales, wetland/pond system, or other measures into the design of the storage system.
- Areas should be as level as possible in order to maximize infiltration rates across the entire structure.
- Both grids and pipe systems have backfill requirements (which must be adhered to) specific to the device.
- Outflow locations (if used) must prevent concentrated flow conditions from developing within the subsurface storage unit.
- Maintenance "ports" should be installed at strategic points to allow for easy inspection and maintenance of the structures.

Maintenance

As mentioned, in high sediment flow conditions, pretreatment is necessary to reduce accumulation in the subsurface detention system. Maintenance of these pretreatment structures can be frequent. The structures themselves should remain relatively maintenance free if proper precautions are taken to limit the amount of sediment and debris that is allowed to accumulate inside the grid or pipe system. Once installed, these systems can have design lives that exceed 50 years, provided they have no exposure to ultraviolet light (U.S. EPA, 2001).

Costs

Given the small amount of maintenance involved in this storm water management measure, a majority of the expense is incurred at the beginning of the project, mainly in materials and excavation and backfill costs. In addition to considering construction costs, the value of available land above the structures should also be considered based on an equivalent aboveground storm water management measure.

Additional Information

Internet Keyword Search:
storm water detention, subsurface detention, retention

PROPRIETARY MEASURES

Proprietary measures are storm water management systems that incorporate one or more water quality treatment principles into a single storm water measure or measures. Proprietary measures are manufactured systems designed to treat storm water runoff. There are a variety of proprietary systems available commercially. These systems consist of a wide variety of technologies designed to remove pollutants from storm water runoff. The pollutant removal efficiency of these measures will vary. Some measures can be modified to increase pollutant removal efficiency by the installation of an in-line filtration system. Manufacturers will typically provide data on pollutant removal and efficiency. Many manufacturers provide independent testing as testimony to the performance of their product.

These systems should be installed according to the recommendations and specifications of the manufacturer. The design and installation of these measures will generally require detailed site investigation, including an assessment of the pollutants within the drainage area.

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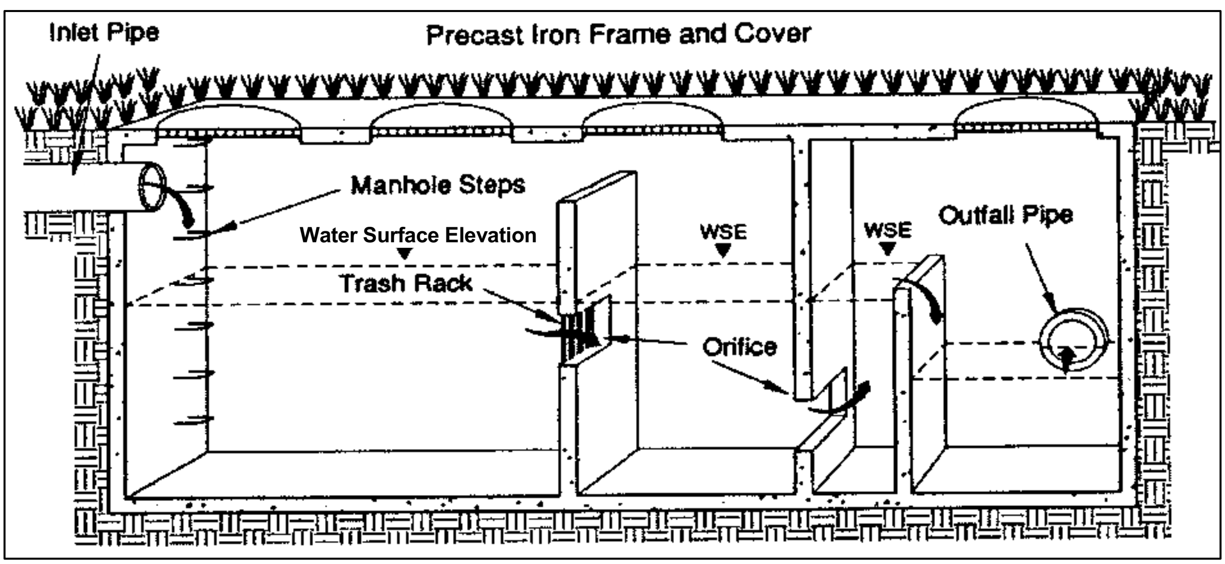
Gravity Oil-Grit Separators

Surface water flowing over an area may pick up pollutants such as sediment (total suspended solids), oil, grease, and other compounds. These pollutants are carried to surface water bodies and can infiltrate into ground water. Some of these pollutants are water soluble while others such as oil, grease, and grit are insoluble. Pollutants which are not water soluble can often be removed through gravitational settling and trapping.

Gravity oil-grit separators *(also known as oil-grit separators) are storm water quality measures designed to remove grit, heavy sediments, oil, grease, debris, and floatable matter from storm water runoff. Gravity oil-grit separators are storm water quality measures that trap and store pollutants removed from storm water runoff for later disposal. This is accomplished through gravitational settling and trapping. Gravity oil-grit separator units contain a permanent pool of water and generally consist of an inlet chamber, a separation/storage chamber, a bypass chamber, and an access port for maintenance purposes. Runoff enters the inlet chamber where the heavy sediments and solids settle out. The flow then moves into the main gravity chamber where further settling of suspended solids takes place. Oil and grease, which initially float, should eventually attach to other particles and settle to the bottom of the second chamber or are collected on filter*

Figure 1: Schematic of a Gravity Oil-Grit Separator



Source: Northern Virginia Regional Commission, 1992 *media. The remaining clarified runoff can then be moved into the outlet chamber and eventually discharged from the structure. Gravity oil-grit separators are compatible with storm drain fittings so they can easily be incorporated into existing storm water systems.*

Application

The most common use of gravity oil-grit separators is in commercial, industrial, and transportation land use areas. They are intended primarily as pretreatment measures for storm water runoff from high-density urban sites or for use in "hotspot" areas such as gas stations and areas with large amounts of vehicular traffic. Their installation should be restricted to the following uses:

- Pretreatment for other structural storm water quality measures.
- High-density urban areas or development sites where space is limited.
- Hotspot areas requiring the control of grit, floatable pollutants, and oil or grease.

Gravity oil-grit separators cannot remove dissolved or emulsified oils and pollutants such as soluble lubricants, coolants, and soluble industrial organics such as alcohol or glycols. Due to the possibility of resuspension of accumulated sediments during heavy storm runoff events, gravity oil-grit separation units are usually installed off-line from the main storm water runoff system. This configuration requires the installation of additional manhole structures to divert the flow from the main conveyance system into the separator for treatment and then divert the treated flow back into the main storm drain conveyance system.

Performance

Testing has shown that gravity oil-grit separators will initially remove a percentage of the total suspended solids when set up in an off-line configuration (see Table 1). Where higher total suspended solid removal rates are required, separators should be used in conjunction with other storm water quality measures.

Gravity oil-grit separators can also facilitate the removal of floatable debris, trash, and petroleum products. The performance of this measure is based on the low solubility of petroleum products and the difference between the specific gravity of water and petroleum products (Georgia Stormwater Management Manual, 2001). Table 1 summarizes the removal efficiency for some commonly encountered pollutants. The rates are conservative percentages for design purposes and derived from sampling data, modeling, and professional judgment.

Table 1: Pollutants Removed Through Gravity Oil-Grit Separators

Substance	Percent Removed
Total Suspended Solids	40
Total Phosphorous	5
Total Nitrogen	5
Fecal Coliform	Insufficient Data
Heavy Metals	Insufficient Data

Source: Georgia Stormwater Management Manual, 2001

Design Specifications

It is important that proper design procedure be followed when installing an oil-grit separator. The following sections on installation and maintenance from the *Georgia Stormwater Management Manual* (2001) list some specifications necessary for proper functioning of a separator unit.

- Contributing area to each unit should be based on the manufacturer's recommendations.
- Can be installed on almost any soil or terrain.
- Should be designed to bypass runoff volumes in excess of their designed flow rate.
- Separation chambers should provide for three separate storage volumes:
  - Volume for accumulation of solids settling at the bottom of the chamber.
  - Volume required to allow enough residence time for the separation of sediments and oils from the storm water.
  - Volume for separated oil storage at the top of the chamber.
- Total wet storage area should be at least 400 cubic feet per contributing acre.
- Four-foot minimum depth of permanent pool.
- Horizontal velocity through the separation chamber should be one to three feet per minute or less. None of the velocities in the unit should exceed the inlet velocity.
- Unit should be watertight to prevent ground water contamination.
- For specific design criteria, consult the manufacturer of the device.

Maintenance

- Inspect the unit on a regular basis (e.g., quarterly).
    - Frequency of unit inspection and maintenance is dependent upon land use, climatological conditions, and gravity oil-grit separator design.
    - Inadequate inspection and maintenance can result in the resuspension of accumulated solids which can cause pollutants to be flushed out of the unit.
- Remove accumulated sediment, oil, grease, and floatables using catch basin cleaning equipment (vacuum pumps) as needed.
- Oil, solids, and floatables removed from the unit must be disposed of according to local, state and federal regulations.
- Manufacturer specifications should be followed for any additional maintenance requirements.

Costs

The cost of installing gravity oil-grit separators is high. The majority of the cost of these systems is the purchase price and installation. After installation, the maintenance costs are low to medium. Gravity oil-grit separators are most effective at removing suspended hydrocarbons and should be considered only in areas where hydrocarbon pollution is a concern.

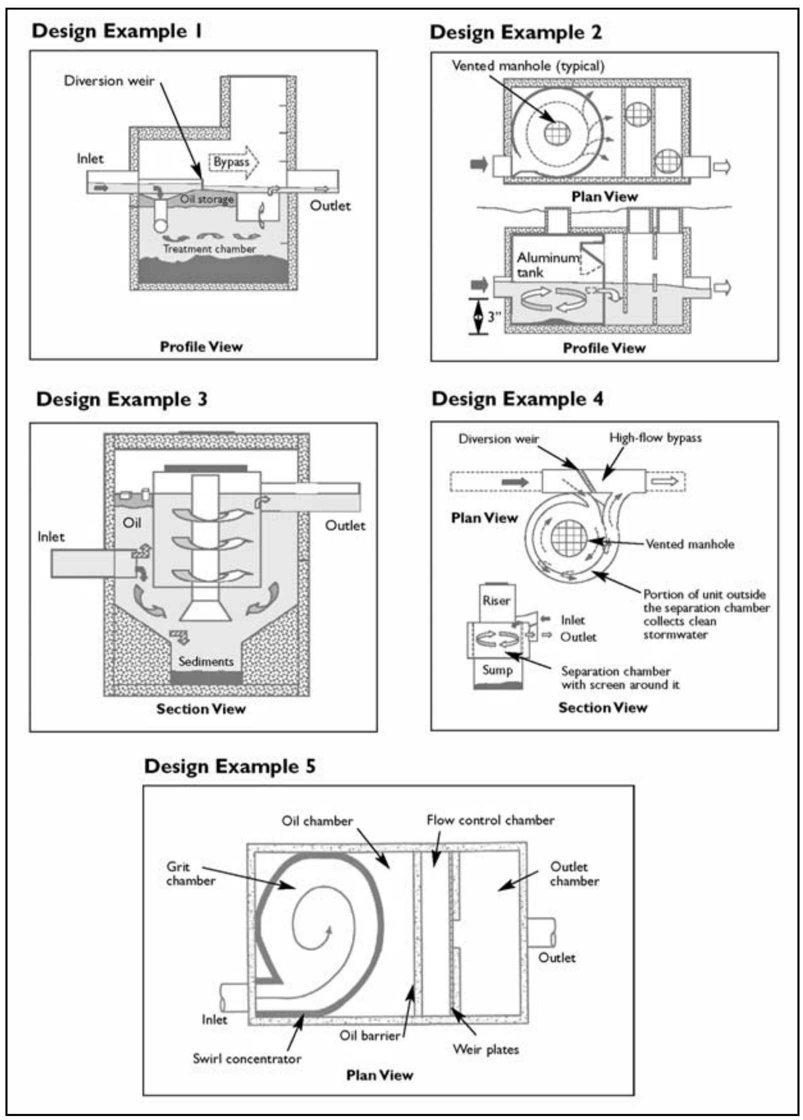
Additional Information

Internet Keyword Search:
gravity separators, oil grit separators

Hydrodynamic Separators

***Hydrodynamic separators**, also known as swirl concentrators, are modifications of traditional oil/grit separators that commonly rely on vortex-enhanced treatment of storm water runoff for pollutant removal. Installed in or adjacent to storm water drainage systems, they are very effective at removing coarse solids, trash, and oil. By concentrating the influent into a swirl or vortex, solids settle out via gravity and are stored in a chamber at the bottom of the separator structure. Most hydrodynamic separator structures also have chambers to trap oil and other floatables. Swirl concentration is the most common technology, however other units available commercially use circular screening or cylindrical sedimentation. Circular screening systems utilize a combination of screens, baffles, and inlet/outlet structures to remove debris, large particles, and large oil droplets. Cylindrical sedimentation systems utilize internal baffles and an oil and sediment storage compartment (Connecticut Stormwater Quality Manual, 2004). The efficiency of hydrodynamic separators is highly dependant upon site-specific conditions but they do represent a valuable method for removing suspended solids from storm water runoff. Figure 1 shows several examples of common hydrodynamic separator designs.*

Figure 1: Common Hydrodynamic Separator Designs



Source: Connecticut Stormwater Quality Manual, 2004

Application

Hydrodynamic separators are extremely effective on their own or in combination with other storm water quality measures. An arrangement where storm water runoff flows exceeding design specifications of the device are passed to a storage facility (extended detention ponds, etc.) for additional treatment can be particularly effective. In addition, they can serve effectively in storm water hotspots such as gas stations, industrial sites, or high vehicle traffic areas where acute pollution is a concern. Their relatively small size makes them ideal for areas where space is a concern or for retrofitting existing sewer lines. All hydrodynamic separators are installed below grade, which minimizes safety issues and does not diminish aesthetics, especially in urban areas where this is often a concern.

Design Specifications

There are a number of structures on the market that utilize hydrodynamic separation technology. The most effective structures combine a swirl unit to remove oils and sediments. Some units have additional flow-through and filter mechanisms that remove oils, trash, and various other pollutants whose specific gravity does not lend them to settling out readily in the swirl concentrator. Differences do exist in the amount of treatment that occurs at full design flows as well as the location of material storage within the unit. These differences should be thoroughly investigated with the manufacturer for given site conditions. Due to the proprietary nature of these devices, hydrodynamic separators should be sited and installed according to the manufacturer's recommendations. Hydrodynamic separator design should use accepted principles of fluid mechanics to demonstrate that the water surface inside the tank can be elevated to a predetermined level in order to prevent the re-entrainment of previously trapped buoyant and nonbuoyant particles. Upstream diversion structures can be used to bypass higher flows around the devices which in most cases are installed in an off-line configuration.

Hydrodynamic separators should be capable of capturing oil, trash, and a minimum of 80 percent of the total suspended solids from the first one-half inch to one and one-half inch rain event. Devices with less than 80 percent total suspended solids removal efficiency should be used in conjunction with other storm water quality measures. The removal efficiency of total suspended solids should be based on standard performance testing (using OK 110 sand) that has been conducted by an independent third party.

Hydrodynamic separators alone may not remove all the targeted pollutants from a site. For example, these systems alone may not remove 80 percent of the lead, copper, or zinc in addition to the polyaromatic hydrocarbons associated with fueling areas. A secondary in-line filter system may be required to achieve these objectives.

When used in combination with detention systems, hydrodynamic separators should be installed upstream and should not be included in the calculations for the required detention volume.

Maintenance

Frequent inspection and cleanout is critical for proper operation of hydrodynamic separators. Recommended inspection and maintenance schedules vary with each manufacturer, but in general hydrodynamic separator structures need to be inspected quarterly and cleaned out accordingly. Hydrodynamic separators should have easy, unobstructed access from the top of the structure to allow for inspection, cleanout, and maintenance. Maintenance typically involves using a vacuum truck to remove accumulated oil, floatables, and sediment. Polluted water and sediment removed from these devices should be properly handled and disposed of in accordance with local, state, and federal regulations.

Costs

The ease of maintenance and long design life of hydrodynamic separators is such that costs, though initially high, should be weighed against similar storm water quality management measures over a long period of time. Costs should be broken down into treatment costs per acre which include operating expenses (maintenance costs and disposal expenses) separate from initial materials and installation costs. In addition, the expense of retrofitting should be examined as an alternative to other retrofit storm water quality management measures which may require more space to mirror the pollutant removal capabilities of these devices.

Additional Information

Internet Keyword Search:
swirl separators, hydrodynamic separators, vortex separator

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Catch Basin Inserts With Treatment Medium

Inserts in storm drain catch basins are used to capture solids, oils, and other harmful chemicals that are either spilled into a drain opening or carried into storm drains by storm water runoff. ***Catch basin inserts*** *are typically comprised of a structural unit that is placed in a catch basin. The unit typically consists of a box, basket, tray, a treatment medium, a primary inlet and outlet, and a secondary outlet to accommodate storm water flows that exceed design.*

Application

This measure is well suited to storm drains in small impervious areas. These areas include parking lots, gas stations, and commercial developments where oils and grease are more prominent in the storm water runoff. They are also applicable where drains are designated to collect spills of grease and oils, such as those found in or near restaurants and vehicle maintenance areas. Catch basin inserts are well suited as a pretreatment measure.

Inserts and the treatment medium come in a variety of materials and sizes. There are organic, inorganic and synthetic mediums. This measure will focus on the use of synthetic mediums. Organic and inorganic materials are usually not suitable for catch basin treatment. Synthetic mediums, although more expensive, are resistant to degradation and offer the option of being cleaned and reused. Table 1 provides details to aid in the selection and application of various materials. The selection of a medium is site specific. Determining which medium to use should be based on the type and quantity of pollutants to be treated.

Table 1: Categories of Synthetic Treatment Mediums

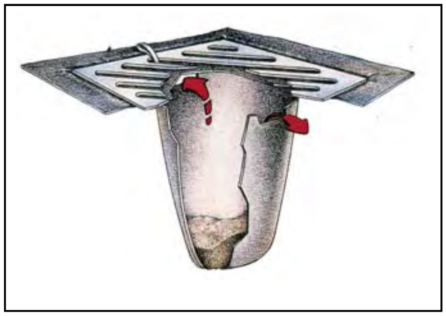
Material	Sorbent Capacity
• Nylon Fiber • Polyethylenes • Plastics	70 times their weight in oil
• Nontoxic, nonhazardous polymers	One pound will adsorb .5 to .67 gallons of oil.
• Solid, spherical plastic particles	Each sphere/particle absorbs up to 27 times its own volume.
• Petroleum-derived polymers	2 to 14 times their weight in oil

Source: U.S. EPA, 2002g

Storm drain inserts can be used for the sorption and active treatment of storm water runoff from parking lots and gas stations. Storm drain inserts typically consist of a filter to trap larger particles and a permeable material to absorb/adsorb oils and other pollutants. Several commercial companies offer a wide variety of storm drain insert models which generally incorporate both storm water treatment measures in one device. These inserts are designed to collect storm water runoff in the storm drain and pass it through the storm water treatment mediums. Storm drain inserts are typically held in place by the storm drain grate or cover.

Design Specifications

As noted above, storm drain inserts allow for filtering of storm water inflow for large particles (sediment, trash and debris) and the sorption of oil and other pollutants. The pollutant removal efficiency is influenced by targeted pollutants and the ability of the product selected to treat the runoff. Frequent maintenance is critical when using these products. Catch basin inserts are not efficient in pollutant removal as are other storm water quality measures. The pollutant loading and site characteristics will influence whether this measure can be used alone or as a pretreatment measure. Following is a list of suggested design parameters for storm drain inserts that will aid in proper application.



Source: State of Idaho Stormwater Manual

- The contributing drainage area needs to be considered when selecting a catch basin insert. Runoff in excess of product specifications may result in premature bypass of runoff. The manufacturer will provide specifications for flow, filtration, and other design specifications.
- Catch basin inserts fit directly into the storm drain basin, allowing for a positive seal around the grate and the prevention of low-flow bypass.
- The maximum height of the storm drain grate above the top of the frame, with the insert installed, should not exceed 3/16 inch, and the grate should be level and non-rocking.
- Catch basin inserts should be easily accessible for inspection, cleanout, and maintenance. Access should not be limited by continuous obstructions such as vehicles and dumpsters.

Maintenance

Storm drain inserts have small volumes and limited retention time to treat runoff. Storm drain inserts require frequent inspection and have very high maintenance requirements. To remain in working order requires cleaning or replacement of the treatment medium. The manufacturer will usually provide information on maintenance requirements for their product. If not properly maintained, they can become clogged, resulting in blocked flow and flooding of up-slope areas. Monitoring schedules should be on the order of at least once a month and after each one-half inch or greater storm event.

Costs

The cost of using absorbents in storm drains that are specifically designed to trap oils, grease and other hazardous materials is a minimal expense when compared to the long term protection that these measures can provide.

The use of a medium for the active treatment of storm water runoff carries a significant cost in terms of inspection frequency and maintenance. This is particularly true once the measure has reached or exceeded its storm water runoff treatment capacity and has to be cleaned or replaced.

Using catch basin insert storm drain treatment measures on a large scale is cost prohibitive and it is generally best to select an alternative storm water treatment measure(s).

Additional Information

Internet Keyword Search:
drain absorbents, storm drain inserts, catch basin inserts, organic, synthetic, inorganic

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CHAPTER 9

Storm Water Quality: Activities

Above photo source: Indiana Project WET, Indiana DNR

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INTRODUCTION TO STORM WATER QUALITY: ACTIVITIES

Storm water management activities include a variety of measures that are specifically targeted to the reduction of pollution. Typically, these activities can be characterized as source controls. Source controls focus on activities that limit the generation of pollutants at the source rather than the treatment of runoff. This can be achieved through effective and innovative planning, education and public outreach, and the day-to-day actions of the public, businesses, and government.

The remainder of this chapter will focus on management and maintenance activities, education and public outreach initiatives, and finally, regulatory program implementation.

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MANAGEMENT & MAINTENANCE ACTIVITIES

In addition to project site design considerations, pollutants can be reduced through project management, operational procedures, and program implementation. These measures are often referred to as source controls. Source controls focus on activities that limit the generation of pollutants at the source rather than the treatment of runoff. Source controls include day-to-day activities and include but are not limited to trash recycling/disposal, washing of equipment and vehicles, and periodic street sweeping. Through their day-to-day activities, private citizens can play a very important role in protecting water quality by collecting and properly disposing of pet waste, reducing and/or properly applying fertilizers and pesticides, participating in neighborhood recycling programs, and properly disposing of household chemicals and wastes.

This section of the manual contains several source control storm water management measures which can be used to effectively reduce the amount of pollutants generated or their introduction into storm water runoff. It is important to keep in mind that these source controls should be part of an integrated storm water management program. They should not be substituted for the implementation of effective permanent storm water quality measures.

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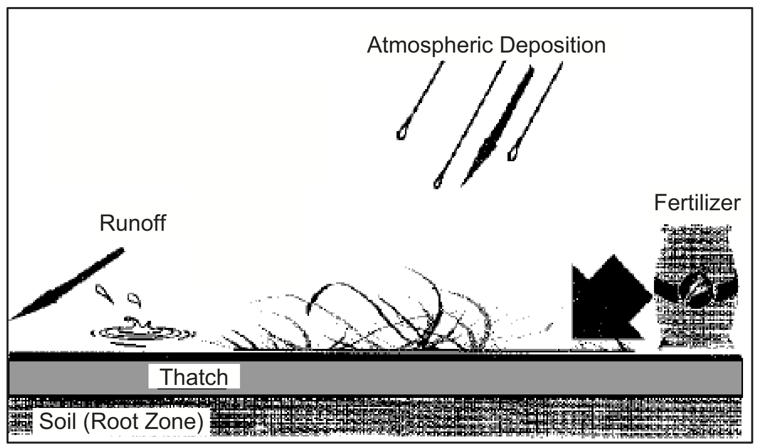
Pesticide & Fertilizer Application

Pesticides and fertilizers are a mixture of chemical substances (many containing toxic materials) and nutrients used on the lawns of homeowners, businesses, industries, and agricultural areas. Nonpoint source pollutants commonly associated with both rural and urban runoff are often from pesticide and fertilizer usage (see Figure 1). Monitoring of urbanized areas has shown a link between chemicals found in lawn care products and urban water quality via surface or ground water. The U.S. Environmental Protection Agency estimated in 1979 that homeowners used 87 million pounds of pesticides annually. Minimizing the impact of nonpoint source pollution is a goal involving the cooperation of everyone.

The proper use of fertilizers and pesticides is critical to minimize impacts to the environment. Management measures associated with this issue are considered source controls and are dependent upon citizens, businesses, municipalities, and government agencies managing day-to-day activities.

Figure 1: Fertilizer Pathway to Urban Streams



Source: Center for Watershed Protection, 2000

Application

Pesticides

Pesticides are defined as chemical compounds used for the control of undesirable plants, animals, or insects. The term includes insecticides, herbicides, algicides, rodentcides, nematicides, fungicides, and growth regulators. These chemicals are typically applied to target specific nuisance plants and organisms. The misapplication or overapplication of pesticides may cause chemicals to leach into the ground water or be transported into surface waters. These compounds can potentially have the same effect on plants and organisms living in the ecosystem that received the runoff as it would have had on the targeted treatment area.

Most products that are purchased through a retailer by homeowners are usually formulated for general use. Commercially available pesticides are formulated at a greater strength and are considered restricted-use products. It is important that those applying pesticides follow the instructions on the label. Restricted-use products require certification and qualifications through appropriate state authorities that have administrative oversight.

Crews associated with businesses, municipalities, governmental agencies, and others should be trained in the application and proper handling of pesticides and, when required, properly certified and licensed.

If there is no other alternative but to use pesticides, the following practices will reduce the amount and impact pesticides have on the environment.

- Select the pesticide to target specific pests.
- Apply according to the label. Do not misapply or overapply pesticides.
- Do not apply pesticides as a preventive measure. Only apply pesticides if absolutely necessary and if a problem exists.
- Do not apply pesticides prior to a rainfall event.
- Avoid application under windy conditions to avoid drift.
- Use pesticides applications that will reduce drifting.
- Use pesticides that are incorporated into the soil.
- Consider the area to which the application will occur and the environmental conditions or potential hazards associated with the application.
- Always store, clean, and dispose of pesticides containers properly.

Fertilizers

Fertilizers and pesticides are often overapplied because they produce high yields, are easy to apply, and are relatively inexpensive (see Table 1). However, there are several toxic waste metals in some fertilizers (not found on labels), as well as other detrimental effects on water quality and the environment.

Table 1: Comparative Chemical Application Rates in Pounds/Acre/Year in Maryland

Chemical	Cropland	Golf Fairway	Greens	Home Lawn (do it yourself)	Home Lawn (lawn service)
Nitrogen	184	150	213	44 – 261	194 – 258
Phosphorus	80	88	44	15	no data
Pesticides	5.8	37.3	45.1	7.5	no data

Source: Schueler & Holland, 2000

Methods to Reduce Fertilizer Runoff

Listed below are several methods and alternatives that can be used to reduce the amount of fertilizer applied. Following these recommendations will lessen the potential for fertilizer runoff and water quality degradation.

- Apply fertilizer to target the species in the application area.
- Reduce leaching by applying fertilizers at a rate equal to plant uptake. Apply small quantities of fertilizer several times during the growing season.
- Substitute natural or slow release organic fertilizers for inorganic products. If using an inorganic product, choose those with a slow release formula.
- Use a mulching mower and cut no more than the top third of the grass. Grass clippings from mowing the lawn contain many of the nutrients that fertilizers provide.
- Do not overapply the amount of fertilizer. The application rate appears on the label. It is recommended that fertilizer application rates be based on soil test results.
- Never apply fertilizer on a windy day or before a storm event is expected.
- Avoid getting fertilizer on driveways, sidewalks, and streets. These areas typically will drain to storm water conveyance systems. Above all, fertilize carefully. Don't let your fertilizer application get into lakes, streams or ponds.

Runoff from unused phosphorus in lawn fertilizer moves across lawns, roads and woods into streams and ditches, and eventually into reservoirs and lakes. The majority of Indiana soils already contain adequate amounts of phosphorus for a healthy lawn, so most lawns don't need the extra food.

The solution to phosphorus runoff is to control the source. Using phosphorus-free lawn fertilizer is one easy way anyone can contribute to better water quality—regardless of where you live. When shopping for lawn fertilizer, look for the three numbers on the lawn fertilizer bag. The middle number indicates the phosphorus content of the fertilizer, so look for a zero. The other numbers indicate the amount of nitrogen (first number) and potassium (third number) in the fertilizer. Phosphorus is needed only on newly seeded lawns or where soil testing indicates a deficiency.

Crews that apply fertilizers for businesses, commercial operations, or governmental agencies should be trained in the proper application and handling of fertilizers.

Cost Considerations

The methods described above are very cost effective and can significantly reduce the amount of pollutants introduced into a watershed. Adopting these measures often requires a change in behavioral attitudes which is typically accomplished through the development and implementation of education and outreach programs. The initial cost spent to reduce chemical pollution of the watershed will be recouped by the money saved from trying to treat polluted runoff.

Additional Information

Internet Keyword Search:

suburban pesticides, suburban fertilizers, pesticide alternatives, lawn fertilizer, fertilizer application

Recycling

Recycling programs seek to encourage the reuse of materials through community involvement in recycling. Recycling reduces the demand for raw materials, saves energy, and conserves resources. The more convenient recycling is to people, the higher the participation rate. As a result, organized recycling programs are often the best way to encourage participation.

Recycling programs offer many benefits to the environment. From a water quality perspective the recycling of industrial wastes minimizes the risk of water contamination from the storage and disposal of the wastes. Domestic recycling encourages responsible disposal of both recyclable and nonrecyclable items which can result in less trash being discarded on the streets and being washed into the waterways. The recycling of products such as batteries is especially good because they contain toxic chemicals which may leach into the waterways when disposed of improperly. Keep leaves, grass clippings and soil out of streets and gutters. Compost leaves and clippings on site, bag them for collection or use a community compost program. Composting yard wastes and leaves is a good way to create topsoil for a community. Equally important, recycling programs raise awareness of the benefits of minimizing and reusing waste.

Application

Residential Recycling

There are several types of recycling programs—residential, industrial, and process and manufacturing recycling. Residential recycling focuses on the recycling of domestically produced wastes. Industrial recycling focuses on the recycling of industrially produced byproducts. This can be a cooperative effort in which two industries exchange byproducts or it can be an individual effort where one industry sells or gives a byproduct to another industry. Processing and manufacturing recycling programs attempt to incorporate byproducts of a process back into the process. The following discussion will focus on collection-based recycling because it is the simplest and most commonly encountered recycling program and lends itself well to community involvement.

Residential recycling programs, sometimes referred to as recycling collection programs, are staffed either by government agencies or private haulers. These programs provide collection and distribution of recyclable goods. The following table lists and summarizes some of the more common types of collection-based recycling programs.

Table 1: Types of Collection Recycling Programs

Government-Staffed Collection Programs Government agencies staff programs which provide curbside, drop-off, or other methods of collection. These programs usually incorporate education, market development, and other activities supporting the collection program. These programs may or may not include privately based contractors.
Hauler-Based Collection Private companies provide recycling collection services to residential, commercial, and industrial waste generators. Sometimes these services are provided under contract with municipal or state governments.
Disposal Facility-Based Collection Establishments which operate solid waste disposal facilities such as incinerators, landfills, transfer stations, and recycling centers where recyclable material is segregated from disposable material provide services which include sorting, baling, grinding, and compacting recyclables for wholesale distribution.

Source: Northeast Recycling Council, Inc., 1998

Additional Information

Internet Keyword Search:
recycling, recycling incentives, recycling programs, curbside recycling

Street Cleaning

Mobile sweepers vacuum pollutants and debris from paved areas. The effectiveness of mobile sweepers at removing sediment and trash from paved areas has increased over the last decade to the point that it now represents a viable solution to controlling nonpoint source pollution. Sediment accumulated on paved surfaces (streets, parking lots, etc.) is a major source of nonpoint source pollution during storm events. Pollutants include sediment particles, debris, trace metals, excess fertilizers from lawn applications, trash, and road salt. Without appropriate storm water quality measures these pollutants can be flushed into streams during storm events. Implementing a street-cleaning program can significantly reduce the amount of nonpoint source pollutants that enter surface waters.

Application

Street cleaning is well suited to urbanized areas where the use of structural storm water quality measures are limited due to the availability of land or the inability to retrofit existing infrastructure. Typical application for a street cleaning program includes streets and parking surfaces associated with residential areas, city/municipal streets, commercial businesses, and industrial sites. Municipal, county, and state agencies may also consider this measure at rest areas and maintenance facilities.

There are a variety of sweepers available commercially. The four most common types of sweepers (U.S. Department of Transportation, Federal Highway Administration, 2002, May) are listed below:

Mechanical Sweepers

This is the most common type of sweeper utilized in the United States. This sweeper utilizes a rotating broom to remove particles and other debris from the paved surface. This method also incorporates a water spray to reduce dust. Water is sprayed in front of the sweeper and particles and other debris are picked up by the rotating broom and carried on a conveyor belt to a storage hopper.

Vacuum-Assisted Sweepers

This sweeper also utilizes a broom to remove particles and other debris from paved surfaces. The operation is similar to the mechanical method by using water to reduce dust. The primary difference between this sweeper and the mechanical sweeper is that the broom directs the particles and debris in the path of a vacuum that transports the material to the storage hopper. The overall efficiency of the vacuum-assisted sweeper is generally higher than a conventional mechanical sweeper.

Regenerative Air Sweepers

Sweeping and removal of particles and debris are achieved through blowing air onto the paved area and immediately vacuuming the material. The materials that are captured are directed to the storage hopper.

Vacuum-Assisted Dry Sweepers

The mechanical operation of these sweepers is completely dry. A specialized rotating brush is used to scratch and loosen particles and dust from the paved surface. The sweeper has a continuous filtration system that collects and retains very fine particles. The filtration system prevents the formation of dust trails that are commonly associated with mechanical sweepers.

Efficiency

Vacuum-assisted sweepers and regenerative air sweepers are typically more efficient than conventional sweepers at removing finer particles. The particles are also more likely to bind with heavy metals, improving the overall performance for pollutant removal. However, the vacuum-assisted dry sweepers have demonstrated a higher removal rate for particles with an aerodynamic diameter less than or equal to ten microns. These sweepers are also designed to meet national ambient air quality standards.

The overall efficiency of sweepers can be optimized by operating at speeds of six to eight miles per hour. It is also critical that brushes are properly adjusted for rotation as per the recommendations of the manufacturer. Sweeping patterns should also be taken into consideration when developing a sweeping program. Generally, two passes per run should be conducted, which will result in the removal of up to 75 percent of total solids present before the sweeping (U.S. Department of Transportation, Federal Highway Administration, *Fact Sheet–Street Sweepers*).

Frequency of Sweeping

In addition to the type of sweeper purchased, the frequency of sweeping also impacts the effectiveness of sweeping programs to diminish nonpoint source pollutants during storm events. An effective street sweeping program can remove several tons of debris annually from city streets (U.S. EPA, NPDES, Pollution Prevention/Good Housekeeping for Municipal Operations, Parking Lot and Street Sweeping, 2007). The Federal Highway Administration estimates that 30 percent removal of dirt can be achieved with a sweeping interval of less than two times the average interval between storms. To achieve 50 percent, sweeping must occur at least once between storms (U.S. Department of Transportation, Federal Highway Administration, 2002, May). In cold climates it is suggested that areas be swept as early as possible in the spring to clean up salt and sand used for winter street maintenance before spring rains wash away this material. A second sweeping should take place in the fall to collect leaf litter.

Regardless of sweeping frequency, it is important to remember that storm water flushes sediment and debris from paved areas into streams, so tailoring your sweeping plan to minimize the amount of sediment and debris present during periods of high precipitation is key. In addition, training in proper sweeping techniques, parking restrictions, and increased concentration on areas of high traffic weigh heavily in the success of sweeping operations. It is better to sweep less frequently, doing a more thorough job, than to sweep more frequently with diminished effectiveness.

Key Considerations

Following are key considerations when designing and implementing a sweeping program to maximize removal of pollutants.

- Emphasize sweeping during wet seasons, or periods of greater precipitation.
- Sweep as close to the curb as possible; this is where dust and dirt collect.
- Impose parking controls during sweeping hours or sweep at times when vehicle obstructions are minimized.
- Sweep heavy traffic areas more frequently.
- Staff and operators should be adequately trained.
- The frequency of sweeping and routes should be selected to optimize efficiency.
- Reduce sources of pollutants. Utilize source controls that include but are not limited to public education and signage.
- Properly dispose of materials collected during sweeping operation. Disposal of all materials should be in accordance with all state and federal regulations.

Federal and state regulations may allow for the reuse of materials collected for fill or other applications. Screening and separation of the materials is required before reuse. Entities considering this option should check with the state regulatory authority.

Cost Considerations

Costs can vary depending on what type of sweeper is chosen, the frequency of sweeping, and the number of sweepers needed. It is important when weighing the costs to realize that higher-priced equipment may be justified by more efficient cleaning and longer usable life spans. A thorough cost analysis should be performed in order to implement the best program for a given budget. Aspects that should be included in every thorough cost analysis are the costs of training, maintenance, material disposal, and labor.

Additionally, these costs should be normalized with information on the efficiency of the sweeper, the targeted particle size, the amount of pavement which can be thoroughly cleaned by each type of sweeper, and the seasonal use restrictions for each model.

Additional Information

Internet Keyword Search:
street sweeping, municipal street cleaning, mechanical sweeper

Road Deicing

Snow and ice removal is an important pavement management practice in areas subject to these conditions. Traditionally there are two methods employed in the removal of ice and snow—mechanical means such as plowing and the use of chemical deicing agents. Deicing agents are chemicals or compounds designed to melt snow or ice on highways. The most frequently used deicing agents are simple salts such as sodium chloride and calcium chloride because they are less expensive than more sophisticated deicing agents. They are applied to roads during conditions of snow and ice. When the snow melts these materials are deposited on the road surface and can be washed into surface waters by storm water runoff. Every year the United States uses between 8 and 12 million tons of salt for deicing purposes and much of it reaches the waterways and ground water. In addition to being corrosive to the frames and body panels of cars, salt has many negative effects on water quality and the environment.

Negative Effects of Salt on the Environment

- Can damage and kill vegetation.
- Depletes oxygen level in waterbodies as it degrades.
- Disrupts ecology of waterbodies.

Application

Types of Deicing Agents

There are several commonly used deicing agents. Each of them has advantages and disadvantages making them best suited for uses under differing conditions. Sodium chloride is the most widely used deicing agent because it is the least expensive. Calcium chloride is the most attractive alternative to sodium chloride because when applied in liquid or pellet form it is less corrosive, fast melting, and only 10 to 15 percent more expensive. It also works better in extremely low temperatures. Table 1 summarizes the characteristics of some of the more commonly used deicing agents.

Alternatives to Deicing Agents

Removing snow prior to compaction by pedestrian or automobile traffic is essential to preventing it from turning into ice. Prompt removal of snow can often negate the need for deicing agents. Mechanical removal can be accomplished using loaders, brushes, or shoveling. The mechanical removal of snow is especially applicable to parking lots, rooftops, and pedestrian walks and should be incorporated into storm water management plans.

Minimizing Environmental Impact

Good management practices and careful site evaluation can minimize the environmental impact of deicing agents. There are two main considerations in regard to deicing agents—application and storage. The most important of these considerations is storage. Deicing agents should be stored in structures or containers that will isolate the material from the weather and storm water runoff (see Figure 1). Table 2 on page 20 lists some suggestions for minimizing the risk of these agents contaminating surface water.

Figure 1: Salt Storage Facility

During storage, road salt should be covered to prevent salt from lumping together or being lost with storm water runoff.

Table 1: Characteristics of Commonly Used Road Deicers

	Sodium Chloride (NaCl)	Calcium Chloride (CaCl)	Potassium Chloride (KCl)	CG-90 (a corrosion-inhibiting salt)	Calcium Magnesium Acetate (CMA) $CaMgCO_2H_3O_2$
Soils	Cl complexes and releases heavy metals; Na can break down soil and decrease permeability.	Cl complexes; Ca can exchange with heavy metals and increase soil aeration and permeability.	Cl complexes; K can exchange with heavy metals.	Same as NaCl, Mg can exchange with heavy metals.	Ca and Mg can exchange with heavy metals. Ca increases soil aeration and permeability.
Effects on Vegetation	Salt spray and splash can cause leaf scorch and kill new plant growth up to 50 feet from the road. Osmotic stress can result from salt uptake. Grass is more tolerant than trees and woody plants. NaCl, CaCl, KCl and CG-90 deplete oxygen in small lakes and streams when degrading.				Little known effect.
Ground Water	Mobile Ca and Na ions reach ground water and their concentration level can increase during times of low flow. Ca, K and Mg can release heavy metals from soil.				
Surface Water	NaCl, CaCl, KCl and CG-90 can cause density stratification in small lakes with closed basins which can lead to anoxica (lack of oxygen) in lake bottoms; often contain nitrogen, phosphorous, and trace metals as impurities; and often occur in concentrations greater than five parts per million.				Can cause oxygen depletion in surface waters.
Minimum Operating Temperature	12° F	–20° F	-----	1° F	23° F
Comments	Most widely used deicing agent.	More effective, lower operating temperature; much more expensive than NaCl; most often used in low temperature conditions.		Provides some corrosion protection, cost competitive, effective at lower temperature than NaCl.	Very expensive, works at slower rate; less efficient so it requires more storage space; most often used on bridges because of low corrosiveness.

Source: Center for Watershed Protection, Stormwater Manager's Resource Center

Table 2: Minimizing the Risk of Water Contamination

Storage • Salt storage piles should be located on impervious surface and completely covered. • Runoff from storage piles should be contained in an appropriate area. • Spills should be cleaned up after loading operations.
Application • Amount of deicer applied should be adjusted to traffic volume and road conditions. • Trucks should be equipped with ground-speed sensors which adjust spreading rates according to speed. • Salt truck drivers and handling personnel should attend training programs to improve spreading efficiency and reduce losses of material. • Drivers should avoid plowing snow from treated surface into piles near waterways.
Additional Suggestions • Identify ecosystems which might be sensitive to salts and use calcium magnesium acetate in these areas. • Apply sand to help traction and reduce the need for deicing agents. • Match deicing agents to pavement temperatures to maximize deicing efficiency. • Minimize the use of deicing agents in areas with low traffic volumes.

Source: Center for Watershed Protection, Stormwater Manager's Resource Center

Cost Considerations

The cost of these measures ranges from zero to high. Simply reducing the amount of salt used will result in money being saved. Using more expensive alternatives to salt can be a high-cost solution. The construction cost of salt storage facilities is high however over time this can result in money being saved because it prevents salt from being lost to rain and snow melt. When developing a plan for responsible use of road deicers it is important to factor in ecological benefit, magnitude of cost increase, and effect on public safety.

Additional Information

Internet Keyword Search:
road deicers, road salt, environmental effects of road salt, road salt storage, road salt alternatives, road salt use reduction

Domestic Animal Waste

Waste from geese, cats, dogs, and other domestic animals is an often overlooked contribution to poor water quality. The waste from these animals, geese in particular, can result in the nutrient enrichment of waterbodies. As a result, the waste from these animals should be disposed of properly to prevent water quality degradation.

Application

Responsible pet owners should pick up after their pet(s); laws in some cities require this. Developments often have designated toileting areas for dogs and may even provide bags to dispose of waste deposited in these areas. Owners of cats, guinea pigs and other indoor animals should double bag waste from the litter box or cage and dispose of it in containers designated for animal waste disposal. This will prevent other residents from being exposed to the waste. When walking dogs, pet owners should take bags with them to pick up any waste left by their dog. Devices exist to assist owners in this process.

While many people enjoy seeing Canada geese in flight, problems can occur when too many geese concentrate in one area. Typically, developers, homeowners, and other landowners unknowingly cause the problem by creating ideal goose habitat. Geese are grazers and feed extensively on fresh, short, green grass. Add a permanent body of water, such as a retention pond, adjacent to their feeding area and you have created the perfect conditions for geese to set up residence, multiply, and concentrate.

Modifying the habitat of existing areas and designing water areas with the use of different types of vegetative cover, rocks and fences can greatly reduce problems with too many geese. Avoid the use of turf grasses near water areas. Using a combination of warm season grasses, wild flowers, wetland plants, legumes, shrubs, and trees will create an aesthetically pleasing environment for residents, reduce maintenance costs (such as weekly mowing), better control soil erosion on pond banks and improve the habitat for other wildlife that will not become a nuisance. For more information on beneficial habitat modifications and controlling geese, contact the Indiana Department of Natural Resources, Division of Fish and Wildlife or visit IDNR's Web site at www.IN.gov/dnr/fishwild/.

When planning a community ordinance it is important to include waste disposal from domestic animals as one of the provisions. Some cities require that pet owners pick up after their pet, however it is beneficial to include it as a community rule as well. This will ensure that residents comply with the meas-

Cost Considerations

The cost of these measures is medium to low. Providing an area for dogs to use is dependent upon land prices. However, the benefits of this measure include a more sanitary living environment, lower groundskeeping costs, and a cleaner residential community. Providing separate containers for disposal of waste from domestic animals is an inexpensive measure and will prevent other residents from coming in contact with the waste.

Additional Information

Internet Keyword Search:
domestic animal waste disposal, animal waste disposal regulations

Vehicle & Equipment Maintenance & Washing Areas

Using environmentally sound measures when maintaining and washing vehicles and equipment can prevent the contamination of ground and surface water by substances (such as oil, antifreeze, solvents, etc.) typically associated with runoff from these areas. Storm water quality management measures needed to reduce pollution from vehicles and equipment maintenance and washing apply not only to businesses, industry, construction, and municipal fleets, but also to the general public. The implementation of simple best management measures can give a large cumulative benefit in terms of pollution prevention.

Application

Table 1 lists common problem areas involved with vehicle and equipment maintenance and washing. Compliance with local regulations and implementation of basic storm water management measures can protect human health and the environment from substances removed during vehicle and equipment maintenance and washing. The measures involved are derived mostly from common sense and maintaining a clean work environment. The storm water management measures listed below are very effective at reducing discharges of untreated vehicle wastes and wash water to the watershed.

Table 1: Potential Sources of Pollutants from Vehicle Maintenance and Washing Areas

Potential Storm Water Contamination Source	Potential Problems	Potential Pollutants
Maintenance Area	Fluid spills during maintenance activities; fuel leaks during fueling	Gasoline, waste fuel, used lubricants, battery acid, coolants
Washing Area	Leaking fluids from vehicles; wastewater from cleaning and washout activities	Sand, lime, silicates, waste fuel, admixtures, wastewater, gasoline

Source: U.S. EPA, 2000

Specifications for vehicle and equipment maintenance storm water quality management measures will vary based on the company involved (i.e., small business, industry, fleet, etc). Larger operations will need to implement more structural changes to accommodate the large amount of vehicle maintenance and washing that occurs. Conversely, small businesses and residences may only need to make small changes and use common sense. The following storm water quality management measures and structures are summarized under three categories—maintenance, fueling, and washing and cleaning.

Vehicle and Equipment Maintenance Management Measures

- Establish a schedule to inspect all vehicles and equipment for leaks.
  - Inspect and clean equipment regularly to prevent leaks and excessive buildup of contaminants.
- Conduct vehicle and equipment maintenance at one location away from storm drains.
- Cover maintenance areas with a permanent roof to help minimize storm water runoff.
- Use drip pans and drop cloths to catch drips and spills when draining or replacing motor oil, radiator coolant, or other fluids.
- Avoid using water to clean work areas. Try to use dry methods to clean up materials. Clean small spills with rags, larger spills with absorbent material.
- Use nontoxic substitutes for chemicals where possible.
- Do not use storm drains for disposal of materials.
  - Store recyclable materials (oil, batteries, etc.) for proper disposal.
  - Wherever possible, connect equipment processing areas to a sanitary sewer or wastewater treatment facility.
- Recycle greases, oil and filters, antifreeze, cleaning solutions, batteries, and transmission fluids through proper disposal agencies.
- Buy recycled engine oil, engine coolant, tires, and other vehicle parts when possible.
- Train employees on reducing pollutant discharge, spill prevention, and cleanup.
  - Be sure that employees are aware of all illegal actions associated with pollutant disposal.

Vehicle and Equipment Fueling Management Measures

- Cover fueling areas to help intercept precipitation and reduce storm water runoff.
- Pave fueling areas with concrete rather than asphalt (gasoline deteriorates asphalt).
- Design fueling areas to drain inward to a sump or an oil-water separator.
  - Perimeter drains can be installed as an alternative to inward-draining areas.
- Discourage "topping off" fuel tanks and install vapor recovery nozzles to control drips.
- Where appropriate, use drip pans to catch spills.
- Clean up spills immediately to minimize safety hazards and prevent spreading.
- Mop up small spills or use absorbent materials. Remove absorbent material promptly.
- Transport industrial equipment to a designated fueling area rather than using mobile fueling.
- Make sure that all employees are trained in proper fueling and cleanup procedures.

Vehicle and Equipment Washing and Cleaning Management Measures

- When possible, use commercial washing and cleaning facilities that employ proper pollution control measures.
- If you cannot use a commercial car wash, use a bucket (not a running hose) to wash and rinse vehicles to conserve water and reduce runoff.
- Use designated wash areas (preferably covered). Use bermed wash areas or other measures to contain wash water (see Table 2).
- Stabilize entrances and on-site roads to reduce off-site transportation of sediments.
- Designate a paved washing site for vehicles where the water will drain down slope.

- Divert wash water to a vegetated area so it can percolate into the ground.
- Or, use at-grade storm drains fitted with inserts. Inserts hang down into a drain's catch basin to filter out solids and other pollutants from rinse-water runoff. Trapped materials can be removed or the inserts replaced.

- Wash vehicles with biodegradable, phosphate-free detergent.
- Use nontoxic cleaning products.
- If possible, use "dry" cleaning methods (such as wiping down) rather than hosing equipment.
- Avoid pressure washing on site if commercial washing facilities are available. If commercial facilities are not practical, design a pressure-washing area that can capture and properly dispose of or recycle all of the wash water. Use high-pressure, low-volume washers to reduce overspray.
- When multi-stage washing is practiced, wash and rinse waters can be recycled by reusing the water from the final stage for the first prewash and rinse stage.
- Properly contain, label, and dispose of cleanup materials (rags, towels, absorbent materials).
- Train employees on proper washing methods.

Structural Control of Storm Water Contamination

Moderate to large-sized operations can surround potential contamination areas with containment diking or curbing. These are temporary or permanent methods of separating the activity area from storm water runoff and containing any pollutants within the structure (see Table 2). Diking and curbing can be constructed out of the same impermeable materials (earth, concrete, asphalt, plastics, etc.) and the terms are sometimes used interchangeably. Diking is usually considered larger than curbing, and includes such structures as retaining walls and earthen and concrete berms. Very small, isolated point sources of potential contamination can be contained by a simple drip pan system.

Cost Considerations

As shown in Table 2, simple methods such as common sense, education, and containment are very effective techniques for reducing storm water pollution. Costs associated with vehicle maintenance and wash areas include building covered or enclosed structures, establishing approved connections to a sanitary sewer system, grading wash areas to drain to sanitary sewers, and increased labor costs associated with special handling of hazardous wastes. The installation of containment structures such as berms, dikes, and curbs, while expensive at first, generally become much less expensive in the long run as pollution is reduced. The cost of wash water containment equipment is usually a one-time expense, and this equipment can be used for a number of years. Recycling and reuse of materials also decrease cost expenditures.

Table 2: Spill Containment Methods

	Application	Limits	Design Parameters	Maintenance
Containment Dike	• Can contain larger spills than curbing. • Containment allows proper disposal or recycling of polluted materials.	• Most expensive construction costs. • Relatively high maintenance. • With larger volumes contained, pollutants may infiltrate into ground water.	• Capable of holding an amount equal to any single spill, and keeping out runoff events. • Material strong enough to safely hold spilled materials (dependent on size and type of potential spills).	• Regular structural maintenance. • Inspect after storm events for overflows. • Treat polluted water before release. • Maintenance of any mechanical parts (e.g., pumps). • Earthen berms must be seeded and the vegetation cover maintained regularly.
Curbing	• Smaller-scale applications. • Containment facilitates proper disposal or recycling of polluted materials.	• Not effective for holding large spills or runoff events. • Requires maintenance.	• Smaller containment area requires special attention to keep spills away from contact and tracking by employees.	• Regular maintenance to prevent overflow. • Regular structural inspection and repairs. • Prompt cleanup of spills.

Source: Idaho Department of Environmental Quality, 2001; Pierce County, 2002

Additional Information

Internet Keyword Search:

maintenance areas, vehicle washing areas, municipal maintenance operations, carwash facilities

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EDUCATION & PUBLIC OUTREACH

As noted in the Management & Maintenance Activities introduction on page 5, pollutants can be reduced through project management, operational procedures, and program implementation. These source controls focus on activities that limit the generation of pollutants at the source rather than the treatment of runoff.

This section of the manual provides public education and outreach source control activities that can be used to achieve pollution prevention. Education and public outreach efforts should be used to educate both youth and adults. Educational programs should focus on creating an understanding of how everyday activities contribute to storm water pollution. Education and public outreach can be achieved through public meetings, school programs, adoption of highways and waterbodies, storm drain marking, and other similar programs.

Source controls should be part of an integrated storm water management program. They should not be substituted for the implementation of effective permanent storm water quality measures.

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Public Participation

To be released at a later time

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Education

Creating a successful urban storm water management program will require the cooperation of the general public. In order to achieve their cooperation, the general public needs information on what causes pollution, indicators of water pollution, and what they can do to reduce and/or prevent further storm water pollution. Surveys in Wisconsin have shown that most people do not understand the impacts of urban storm water runoff on water quality. To a large extent the public is unaware of solutions to the pollution problem (see Figure 1). However, there is still a willingness, even from an uneducated public, to support pollution cleanup programs (see Figure 2). A large part of the pollution problem arises because the public is not aware of the impact their actions have on the environment. A simple diagram such as Figure 3 could make the public aware of how to properly dispose of common pollutants found in storm water, thereby decreasing the likelihood of improper disposal of materials into the storm water system. It has been shown that the public can be either helpful or detrimental to the success of storm water management programs, since individual activities play a leading role in reducing storm water impacts in urbanized areas. The key behind getting strong public support begins with education and outreach programs to make the public aware of the problem and potential solutions.

Figure 1: General Public's Knowledge of Storm Water Control

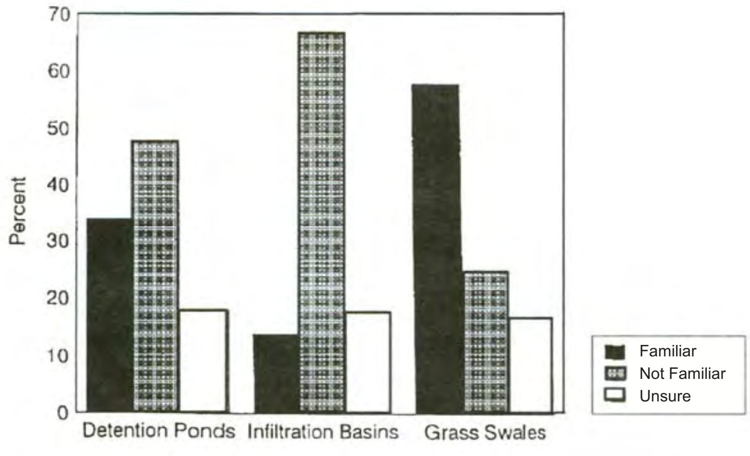
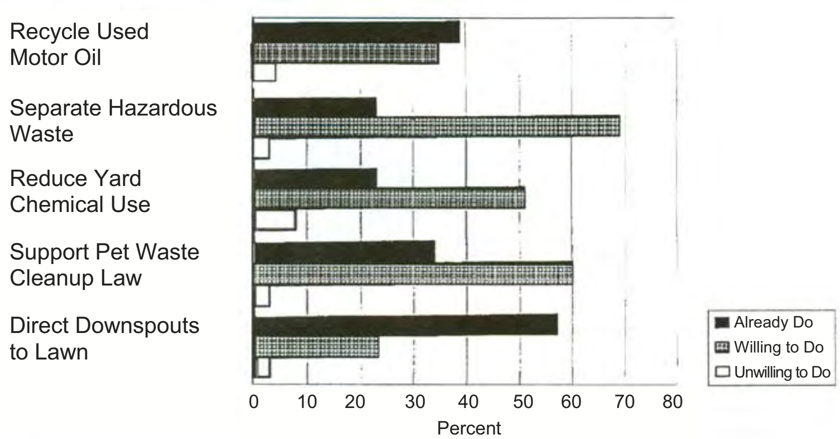


Figure 2: Public's Willingness to Partake in Pollution Prevention Practices



Source: Nowak, Peter J. 1990. "Water Quality in the Milwaukee Metropolitan Area: The Citizens' Perspective." University of Wisconsin Environmental Resource Center. Madison, Wisconsin.

Figure 3: Household Waste Disposal Guide

Kitchen, Bathroom & Household	
Aerosols (empty)	🗑
Batteries (alkaline)	🚚 🗑
Batteries (containing mercury)	🚚
Batteries (rechargeable)	🚚
Cleaners (tub, tile, ammonia based, etc.)	∿
Cosmetics	🗑
Empty Solvent/Cleaner Containers (dry)	🗑
Expired Medicine	🗑
Fats, Oils, Grease	🗑
Glue (water based)	🗑
Glue (with solvents)	🚚
Hair Relaxer	∿
Hairspray, Other Aerosols	🚚
Insect Poison/Bug Spray	🚚
Lighter Fluid	🚚
Moth Balls	🚚
Nail Polish & Remover	🚚
Oven Cleaner	🚚
Rubbing Alcohol	∿
Permanent Lotions	∿
Septic Tank Degreasers	🚚
Shoe Polish	🗑
Toilet Bowl Cleaner	∿
Window Cleaner	∿

Garage & Workshop	
Antifreeze	🚚 ♻
Auto Batteries	🚚 ♻
Brake Fluid	🚚 ♻
Epoxy, Fiberglass	🚚
Gasoline, Diesel, Fuel Oil	🚚
Metal Polish	🚚
Mineral Spirits	🚚
Motor Oil	🚚 ♻
Paint (latex, oil, lacquer)	🚚
Paint Thinner, Strippers	🚚
Putty, Grout, Caulking	🗑
Rust Remover	🚚
Transmission Fluid	🚚 ♻
Varnish	🚚
Windshield Washer Fluid	∿
Wood Preservatives	🚚

Garden	
Fertilizer (with weed killer)	🚚
Fertilizer (without weed killer)	🗑
Herbicides	🚚
Pesticides	🚚
Rat/Mouse/Gopher Poison	🚚

Key

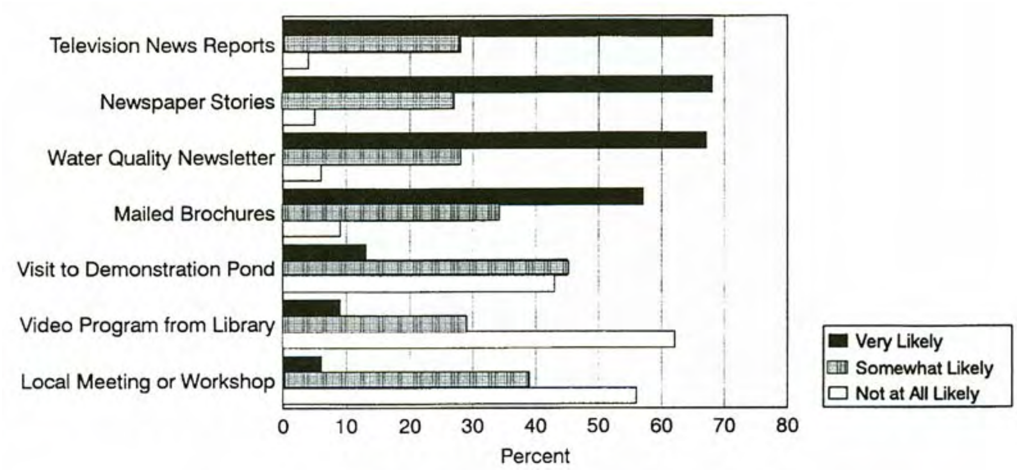
∿ This symbol represents products that can be safely poured down the drain or flushed in the toilet with plenty of water. Homeowners using septic tanks should consider alternate disposal and try to purchase these items sparingly.

🗑 This symbol represents products that can be safely disposed of in the garbage.

🚚 This symbol indicates you should contact your local household hazardous waste program for proper disposal instructions.

♻ This symbol represents products that should be recycled.

Figure 4: Success of Media in Catching Public's Attention



Source: Nowak, Peter J. 1990. "Water Quality in the Milwaukee Metropolitan Area: The Citizens' Perspective." University of Wisconsin Environmental Resource Center. Madison, Wisconsin.

Application

Education Programs

Education of the general public is a shared responsibility, and for that reason it is often neglected. Therefore, the first and foremost goal of any storm water management program should be the formation and implementation of an education and outreach program. Table 1 describes the steps involved and gives examples of how to form an all-encompassing educational program.

There are several benefits to having a well-informed public.

- Citizens who understand what behaviors cause decreases in water quality and the effect of poor water quality in the community are less likely to perform acts that have negative impacts.
- An aware public is much more likely to notice and alert the proper authorities to potentially serious problems within the system. A pollution hotline could be put into effect so hazardous materials spills can be dealt with quickly before the problem becomes catastrophic.
- Public education can be integrated into educational components of private organizations and groups that will hopefully become proactive in maintaining a healthy storm water system.
- Opportunities to create community activities and links with the local government are formed. Coordinated programs regarding storm water pollution prevention activities could include things like stream monitoring, stream cleanups, adopt-a-stream programs, tree planting days and storm drain stenciling.

Table 1: Development of an Education Program

Steps	Description	Examples
Targeting Audience	Financial and labor limitations make it necessary to target audiences. Prioritize by targeting those with the most impact on managing urban storm water.	<u>Public That Must Act</u> • Government officials, developers, owners of industrial property, and urban residents. <u>Public Actively Supporting Change</u> • Local government associations, service groups, environmental groups, water resource groups, concerned citizens. <u>Future Supporters</u> • Youth, teachers, general public.
Identifying Issues	Focus on single issues that are relevant to the local community. Cover only a few issues each year to avoid overwhelming the public and making the problems seem impossible to solve.	<u>Urban Runoff</u> Impacts on water quality and recreation, source of pollutants, effective solutions. <u>Pollution Prevention</u> • Pesticide and fertilizer application. • Clipping and leaf disposal. • Pet waste cleanup. • Sweeping streets and parking lots. • Automotive care, disposal of used motor oil.
Distribution of Information	Information pertaining to pollution and their environment must be distributed and made available to the general public for education to occur. More people learn by everyday media than through special workshops (see Figure 4).	<u>Methods to Distribute Information</u> • Brochures and fact sheets. • Utility bill inserts. • Internet Web site. • Education programs. • Special events or workshops. • School curricula. • Volunteer educators.
Selecting Appropriate Activities	Effective activities must be catered towards the audience, their interests, and the topic being discussed.	<u>For Example</u> • Dog owners are more interested in pet waste topics. • School children are interested in community problems with fun, hands-on learning activities.
Measuring Success	All education programs need evaluation to measure the effect of the program. Evaluations will show what techniques worked and what still needs revision.	<u>Evaluation Indicators</u> • Number of people effected by the program. • Reactions of people to the issues. • What people learned (pretest/post-test). • How people acted on that knowledge. • Improvement in water quality regarding issues dealt with during that year.

Tips for an Education Program

- The education program should be given specifically to someone responsible for designing and implementing the program.
- Choose only a few important topics relevant to the community to do each year. Too much information can be overwhelming and discouraging to the public.
- Target the audiences with the largest impact on water quality first and cater your program to their interests in order to make them more receptive.
- Start with the basics of understanding the problem and how their actions can impact whether this pollution problem is solvable or is going to heavily impact the community in the future. Tell them specifically what, when, how, and where they can participate in preventing or cleaning up pollution.
- Spend the money necessary to achieve high quality. In the long run, preventing pollution problems rather than trying to use structural storm water techniques to improve water quality will save more money.
- Keep your messages simple. Often, the public will ignore messages that are too long or hard to understand. Start small to grab their attention, then as their interest and awareness increases, so too can the messages.
- Make the messages positive. Make them believe individuals can make a difference, because they can. Also, they need to believe their participation is improving their standard of living, as well as the environment.
- Repeat the message. Messages must be repeated several times from credible sources before people will start to believe in them.
- Provide feedback. If the public realizes what a positive, large impact they have made on the environment, they will be more than willing to put more effort into storm water pollution prevention techniques.

Additional Information

Internet Keyword Search:
environmental education, storm water education, local storm water plans

Indiana Resource:
Indiana Department of Environmental Management

Storm Drain Marking

Source: Indiana Project WET, Indiana DNR

Storm drain marking *consists of labeling a storm drain inlet with a preprinted marker, tile, sticker, or stencil that reads "Dump No Waste–Drains to River," "Drains to Stream," or a similar written message that denotes that storm water entering the drain flows through the enclosed drainage system and discharges to a stream, open drainage channel, or other water body.*

Storm drain marking is intended to serve as a visual reminder of the storm drain-to-river connection and give citizens a better understanding of the fate of urban runoff and its effect on water quality. Polluted runoff can harm Indiana's waterways which are often used for recreational purposes such as fishing and swimming and as a drinking water supply in many communities. The United States Environmental Protection Agency recommends storm drain marking as a public education/outreach and public participation/involvement activity for municipalities that are required to comply with the 1972 National Clean Water Act National Pollutant Discharge Elimination System Phase II Storm Water Regulatory Program.

Nonpoint source pollution is pollution that originates from many diffuse and difficult-to-identify sources whereas point source pollution originates from a single, traceable source such as a pipe. Rainwater that washes soil, street litter, oil, leaves, grass clippings, pet wastes, and fertilizers into storm drains is classified as nonpoint source pollution. This untreated storm water can pollute the receiving waterway or waterbody. Although individual storm

Figure 1: Trash Collected Around Storm Drain Inlet Grates

Source: Indiana Project WET, Indiana DNR *drains may contribute small amounts of pollutants, the combination of many storm drains can cause a negative impact on water quality.*

Many people do not realize that polluted storm water flowing into a storm drain or chemicals, automotive fluids, and household wastes dumped into a storm drain is not cleaned or treated before it discharges into a river, stream, lake, or other waterbody.

Application

Marking Methods

Adhesive or preglued vinyl curb markers or stenciling are the most common methods used to mark storm drains. The method chosen will depend on a community's needs and budget.

Adhesive or preglued vinyl markers are attractive, quick and easy to apply, last several years, and require little to no maintenance. Stenciling, however, reaches a larger number of people because stenciled messages are not as permanent and require volunteers to come back in a year or two to restencil messages, thereby educating a new group of volunteers.

Who Can Participate

Storm drain marking is an effective service learning or civic learning project for schools, scout groups, homeowner associations, 4-H clubs, municipalities, or any organization wanting to make a positive impact on their community.

While marking the storm drain identifies the issue to the passersby, the real important impact is the marking activity itself. It connects volunteer groups with the watershed and educates them on how human activities impact water quality.

Permission

The first step to a successful storm drain marking program is to obtain written permission. This will usually require contacting the local government entity that manages the storm drain system with the community (e.g., Public Works Department). Storm drain marking done on private property such as business parking lots will also require contacting and obtaining permission of the landowner(s).

Supplies

The selection and quantity of supplies for storm drain marking will depend on the method chosen and the number of storm drains to be marked. Following is a general list of supplies that are essential to conducting a safe and effective storm drain marking program.

- Safety vests or brightly colored t-shirts.
- Wire brush or broom (for surface preparation).
- Dust pan.
- Garbage bags.
- Safety cones.
- Marking materials.

It is also important to keep in mind that each work group will need their own set of supplies.

Site Preparation & Installation

Proper surface preparation is key to any storm drain marking program. Surfaces must be in good condition, free of loose material, grit, and dirt, etc. and must be clean and dry for paint or an adhesive marker to properly adhere to the surface. As always, it is important to read and follow the manufacturer's directions and recommendations when applying the storm drain marking.

Additional Information

Internet Keyword Search:
storm drain marking

Indiana Resource:
Storm Drain Marking Manual
www.stormdrain.IN.gov

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REGULATORY PROGRAM IMPLEMENTATION

There are a number of storm water regulatory programs that are administered in Indiana. These programs are focused on both storm water quality and storm water quantity. The state administers two programs that are focused on storm water quality. These programs are:

- **Construction/Land Disturbance Storm Water Permitting (327 IAC 15-5, Rule 5)**

  327 IAC 15-5 is a performance-based regulation designed to reduce pollutants, principally sediment, that is a result of soil erosion and other activities that are associated with construction and/or land disturbing activities. The requirements of 327 IAC 15-5 apply to all persons who are involved in construction activity (which includes clearing, grading, excavation and other land disturbing activities) that results in the disturbance of one (1) acre or more of total land area. If the land disturbing activity results in the disturbance of less than one (1) acre of total land area, but is part of a larger common plan of development or sale, the project is still subject to storm water permitting.

- **Municipal Separate Storm Sewer System Permitting (327 IAC 15-13, Rule 13)**

  327 IAC 15-13 regulates municipal separate storm sewer systems (MS4s). MS4s are defined as a conveyance or system of conveyances owned by a state, city, town, or other public entity that discharges to waters of the United States and is designed or used for collecting or conveying storm water.

  Entities designated by the state must develop a local storm water program. The implementation of this program is guided by a storm water quality management plan (SWQMP). The SWQMP must be based on six minimum control measures, including public education, public involvement, illicit discharge and detection, construction/land disturbance runoff, post-construction runoff, and good housekeeping. Several of these measures require MS4s to establish ordinances and enforcement mechanisms.

In addition to the programs administered by the state, many communities across the state have taken the initiative to adopt ordinances to address both storm water quality and quantity. These local regulatory programs are typically administered by local units of government including municipalities, counties, towns, and cities.

This section of the manual provides guidance on the development of regulatory programs. This includes the development and implementation of ordinances and the administration and enforcement of storm water regulations.

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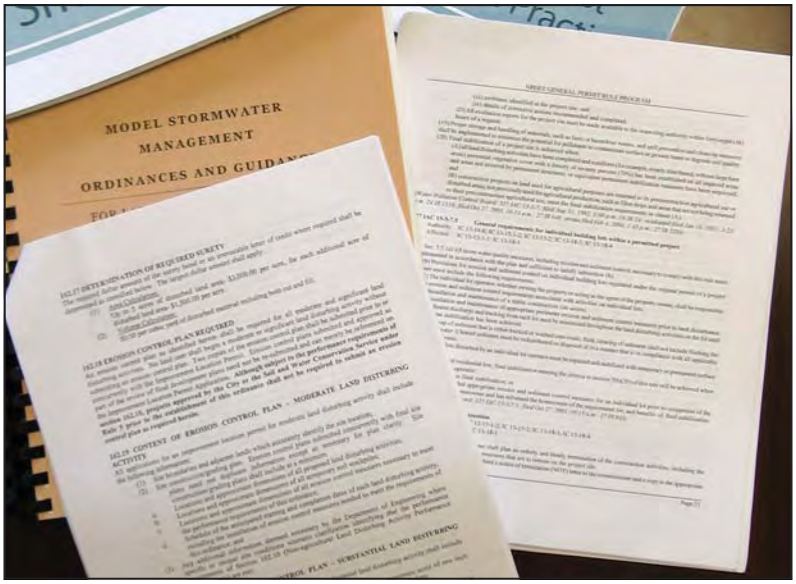
Ordinances



To be released at a later time

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Compliance & Enforcement

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APPENDIX A — GLOSSARY OF TERMS

AASHTO Classification. The official classification of soil materials and soil aggregate mixtures for highway construction used by the American Association of State Highway and Transportation Officials.

Abutment. The sloping sides of a valley that support the ends of a dam.

Acre-Foot. The volume of water that will cover one acre to a depth of one foot.

Advanced Treatment. Pollutant removal techniques typically used in drinking water treatment processes but with potential for application as advanced treatment options for storm water. These treatment techniques include ion exchange, reverse osmosis, disinfection, ultra filtration, alum injection, and use of water-soluble anionic polyacrylamide (PAM).

Aggregate. (1) The sand and gravel portion of concrete (65% to 75% by volume), the rest being cement and water. *Fine aggregate* contains particles ranging from ¼ inch down to that retained on a 200-mesh screen. *Coarse aggregate* ranges from ¼ inch up to 1½ inch. (2) That which is installed for the purpose of changing drainage characteristics

Alluvial Soils. Soils developed from transported and relatively recently deposited material (alluvium) characterized by a weak modification (or none) of the original material by soil-forming processes.

Alluvium. A general term for all detrital material deposited or in transit by streams, including gravel, sand, silt, clay, and all variations and mixtures of these. Unless otherwise noted, alluvium is unconsolidated.

Alternative Site Design. Innovative site design practices have been developed as alternatives to traditional development to control storm water pollution and protect the ecological integrity of developing watersheds. Research has demonstrated that alternative site design can reduce impervious cover, runoff volume, pollutant loadings, and development costs when compared to traditional development.

Alum Injection. Injection of aluminum phosphate (alum), which has been used extensively as a flocculent in pond and lake management applications, for reducing concentrations of fine sediment and phosphorus in storm water discharges to eutrophic waterbodies.

Anoxica. Lack of oxygen.

Anti-Seep Collar. A device constructed around a pipe or other conduit placed through a dam, levee, or dike for the purpose of preventing soil movement and piping failures.

Anti-Vortex Device. A device placed at the entrance to a pipe conduit structure, such as a drop inlet spillway or hood inlet spillway, to prevent air from entering the structure when the pipe is flowing full.

Apron. A pad of nonerosive material designed to prevent scour holes from developing at the outlet ends of culverts, outlet pipes, grade stabilization structures, and other water control devices.

Aquatic Bench. A ten-foot wide bench located around the inside perimeter of a permanent pool that is normally vegetated with aquatic plants to provide pollutant removal.

Aquifer. An underground porous, water-bearing geological formation. The term is generally restricted to materials capable of yielding an appreciable supply of water.

ASTM. American Society for Testing Materials, an association that publishes standards and requirements for materials used in the construction industry.

Barrel. A conduit placed through a dam, levee, or dike to control the release of water.

Baseflow. The portion of streamflow that is not due to storm runoff but is the result of ground water discharge or discharge from lakes or similar permanent impoundments of water.

Bearing Capacity. The maximum load that a material can support before failing.

Bedrock. The more or less solid rock in place either on or beneath the surface of the earth. It may be soft, medium, or hard and have a smooth or irregular surface.

Bentonite. A highly plastic clay consisting of the minerals montmorillonite and beidellite that swell extensively when wet. Often used to seal soil to reduce seepage losses.

Berm. A man-made embankment consisting of a deposit of soil, rock, or other material, often used to form an impoundment for the purpose of confining or controlling water.

Biochemical Oxygen Demand (BOD). A measure of the quantity of organic material that can be decomposed through oxidation by microorganisms.

Bioretention. A practice to manage and treat storm water runoff by using a specially designed planting soil bed and planting materials to filter runoff stored in a shallow depression. The areas consist of a mix of elements, each designed to perform different functions in the removal of pollutants and attenuation of storm water runoff.

Borrow Area. A source of earth fill material used in the construction of embankments or other earth fill structures.

Building Setbacks. The distance between a structure and a property boundary (front, rear, or side) of the lot on which the structure is located.

Capillary Action. The tendency of drier soil particles to attract moisture from wetter portions of soil.

Catch Basin. A chamber usually built at the curb line of a street for the admission of surface water to a storm sewer or subdrain, having at its base a sediment sump designed to retain grit and detritus below the point of overflow.

Catch Basin Inserts. A structure, such as a tray, basket, or bag, that typically contains a pollutant removal medium (i.e., filter media) and a method for suspending the structure in the catch basin. They are placed directly inside of existing catch basins where storm water flows into the catch basin and is treated as it passes through the structure.

Channel. A natural stream or excavated ditch that conveys water.

Channel Stabilization. Protecting the sides and bed of a channel from erosion by controlling flow velocities and flow directions using jetties, drops, or other structures and/or by lining the channel with vegetation, riprap, concrete, or other suitable lining material.

Channelization. Alteration of a stream channel by widening, deepening, straightening, or paving certain areas to improve flow characteristics.

Check Dams. Small temporary dams constructed across a swale or drainage ditch to reduce the velocity of concentrated storm water flows.

Chicken Wire. A woven wire fabric with an opening size of about 1½ inches.

Chute. A high-velocity, open channel for conveying water down a steep slope without erosion.

Clay. (1) Soil fraction consisting of particles less than 0.002 mm in diameter. (2) A soil texture class that is dominated by clay or at least has a larger proportion of clay than either silt or sand.

Coagulant. A chemical added to wastewater or storm water that destabilizes the surface charge of fine particles, allowing the particles to come together to form larger particles that can be more easily removed by gravity, settling, and other physical treatment processes. Alum is a common coagulant used in lake management applications and sometimes used for storm water treatment.

Cohesion. The capacity of a soil to resist shearing stress, exclusive of functional resistance.

Cohesive Soil. A soil that, when unconfined, has considerable strength when air-dried and significant strength when saturated.

Combined Sewer Overflows (CSOs). Combined sewers collect both storm water runoff and sanitary wastewater in a single set of sewer pipes. When combined sewers do not have enough capacity to carry all the runoff and wastewater or the receiving water pollution control plant cannot accept all the combined flow, the combined wastewater overflows from the collection system into the nearest body of water, creating a CSO.

Companion (Nurse) Crop. A crop sown with another crop that will germinate quickly and provide a protective vegetative cover until the preferred species can become established. The crop, usually small grain, is sown with a legume or perennial grass species.

Compost. Organic residue (or a mixture of organic residue and soil) that has undergone biological decomposition until it has become relatively stable humus.

Contour. An imaginary line on the surface of the earth connecting points of the same elevation.

Cultipacker Seeder. A seeder equipped with an attachment that will firm the seedbed to increase seed-to-soil contact.

Cut. (1) A portion of land surface or area from which earth has been removed or will be removed by excavation. (2) The depth below the original ground surface to the excavated surface.

Cutoff Trench. A long, narrow excavation (keyway) constructed along the center line of a dam, dike, levee, or embankment and filled with relatively impervious material intended to reduce seepage of water through porous strata.

Cutting. A detached leaf stem or piece of root that is encouraged to form roots. A *greenwood cutting* is made during the period of active growth. A *hardwood cutting* is made during the dormant season.

Cut-and-Fill. The process of earth grading by excavating part of a higher area and using the excavated material for fill to raise the surface of an adjacent lower area.

Dam. A barrier to confine or impound water for storage or diversion, to prevent gully erosion, or to retain soil, sediment, or other debris.

Deep Sump Catch Basins. Storm drain inlets that typically include a grate or curb inlet and a sump to capture trash, debris and some sediment, and oil and grease. Also known as an oil and grease catch basin.

Deicers. Materials applied to reduce icing on paved surfaces. These consist of salts and other formulated materials that lower the melting point of ice, including sodium chloride, calcium chloride, calcium magnesium acetate, and blended products consisting of various combinations of sodium, calcium, magnesium, chloride, and other constituents.

Deicing Constituents. Additives included in deicing materials to prevent caking and inhibit corrosion.

Design Life. The period of time for which a measure or practice is expected to perform its intended function.

Desilting Area. An area of grass, shrubs, or other vegetation used for inducing deposition of silt and other debris from flowing water. Located above a stock tank, pond, field, or other area needing protection from sediment accumulation.

Detention. Managing storm water runoff by temporary holding and controlled release.

Detention Time. The theoretical time required to displace the contents of a tank or unit at a given rate of discharge (volume divided by rate of discharge).

Dewatering. The removal of water temporarily impounded in a holding basin.

d_{50}. A term used to define rock gradations. In a representative sample, 50% of the rock fragments will have a diameter larger than the d_{50} size and 50% will be smaller.

Dibble Bar. A heavy metal tool with a blade and foot pedal used to open holes for planting seeds, sprigs, cuttings or seedlings.

Dike. An embankment to confine or control water. Often built along the banks of a river to prevent overflow of lowlands; a levee.

Discharge. Usually the rate of water flow. A volume of fluid passing a point per unit of time, commonly expressed as cubic feet per second, cubic meters per second, gallons per minute, or millions of gallons per day.

Dissolved Pollutants. Non-particulate pollutants typically removed through removal mechanisms such as adsorption, biological uptake, chemical precipitation or ion exchange.

Diversion. A channel with a supporting ridge on the lower side constructed at the top, across, or bottom of a slope for the purpose of controlling surface runoff.

Diversion Dike. A barrier built to divert surface runoff.

Divide (Drainage). The boundary between watersheds.

Downstream Analysis. Calculation of peak flows, velocities, and hydraulic effects at critical downstream locations to ensure that proposed projects do not increase post-development peak flows and velocities at these locations.

Drain. A buried slotted or perforated pipe or other conduit *(subsurface drain)* or a ditch *(open drain)* for carrying off surplus ground water or surface water.

Drainage. The removal of excess surface water or ground water from land by means of ditches or subsurface drains. Also see *Natural Drainage.*

Drainage (Soil). As a natural condition of the soil, drainage refers to both the frequency and duration of periods when the soil is free of saturation. Drainage conditions are defined as:

Well drained – Excess water drains away rapidly, and no mottling occurs within 36 inches of the surface.

Moderately well drained – Water is removed from the soil somewhat slowly, resulting in small but significant periods of wetness, and mottling occurs between 18 and 36 inches.

Somewhat poorly drained – Water is removed from the soil slowly enough to keep it wet for significant periods but not all of the time, and mottling occurs between 8 to 18 inches.

Poorly drained – Water is removed so slowly that it is wet for a large part of the time, and mottling occurs between 0 and 8 inches.

Very poorly drained – Water is removed so slowly that the water table remains at or near the surface for the greater part of the time; there may also be periods of surface ponding; the soil has a black to gray surface layer with mottles up to the surface.

Drainage Area. The area draining into a stream at a given point. It may be of different sizes for surface runoff, subsurface flow and base flow, but generally the surface runoff area is considered as the drainage area.

Drainageway. A natural or artificial depression that carries surface water to a larger watercourse or outlet, such as a river, lake, or bay.

Drawdown. Lowering of the water surface in an open channel, lake or ground water.

Drop Inlet. A structure in which water drops through a vertical riser connected to a discharge conduit or storm sewer.

Drop Spillway. A structure in which the water drops over a vertical wall onto an apron at a lower elevation.

Drop Structure. A structure for dropping water to a lower level and dissipating its surplus energy without erosion.

Dry Detention Pond. Storm water basin designed to capture, temporarily hold, and gradually release a volume of storm water runoff to attenuate and delay storm water runoff peaks. Dry detention ponds provide water quantity control (peak flow control and stream channel protection) as opposed to water quality control. Also known as "dry ponds" or "detention basins."

Dry Well. Small excavated pits or trenches filled with aggregate that receive clean storm water runoff primarily from building rooftops. Dry wells function as infiltration systems to reduce the quantity of runoff from a site. The use of dry wells is applicable for small drainage areas with low sediment or pollutant loadings and where soils are sufficiently permeable to allow reasonable rates of infiltration.

Earth Dam. A dam constructed of compacted suitable soil materials.

Earth Embankment. A man-made deposit of soil, rock, or other material often used to form an impoundment.

Emergency Spillway. Usually a vegetated earth channel used to safely convey flood discharges around an impoundment structure.

Energy Dissipater. A device used to reduce the energy of flowing water to prevent erosion.

Environment. The sum total of all the external conditions that may act upon a living organism or community to influence its development or existence.

Erodibility. Susceptibility to erosion.

Erosion. The wearing away of the land surface by water, wind, ice, gravity, or other geological agents. The following terms are used to describe different types of water erosion:

Accelerated erosion – Erosion much more rapid than normal or geologic erosion, primarily as a result of the activities of man.

Channel erosion – An erosion process whereby the volume and velocity of flow wears away the bed and/or banks of a well-defined channel.

Gully erosion – An erosion process whereby runoff water accumulates in narrow channels and, over relatively short periods, removes the soil to considerable depths ranging from 1-2 feet to as much as 75-100 feet.

Rill erosion – An erosion process in which numerous small channels only several inches deep are formed; occurs mainly on recently disturbed and exposed soils (*see Rill*).

Splash erosion – The spattering of small soil particles caused by the impact of raindrops on wet soils; the loosened and spattered particles may or may not be subsequently removed by surface runoff.

Sheet erosion – The gradual removal of a fairly uniform layer of soil from the land surface by runoff water.

Erosion and Sediment Control. A measure placed, constructed on, or applied to the landscape that prevents or curbs the detachment of soil, its movement and/or deposition.

Erosion and Sediment Control System. 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 a discharge from the construction site.

Excess Rainfall. The amount of rainfall that runs directly off an area.

Filter Blanket. A layer of sand and/or gravel designed to prevent the movement of fine-grained soils.

Filter Fabric. A woven or non-woven, water-permeable material generally made of synthetic products such as polypropylene and used to trap sediment or prevent the movement of fine soil particles. Often used instead of a filter blanket.

Filter Strip. Usually a long, relatively narrow area of undisturbed or planted vegetation used to retard or collect sediment for the protection of watercourses, reservoirs, or adjacent properties.

Filtering Practices. Practices that capture and store storm water runoff and pass it through a filtering media such as sand, organic material, or soil for pollutant removal. Storm water filters are primarily water quality control devices designed to remove particulate pollutants and, to a lesser degree, bacteria and nutrients.

Flood Peak. The highest stage or greatest discharge attained by a flood event, thus peak stage or peak discharge.

Flood Stage. The stage at which overflow of the natural banks of a stream begins.

Floodplain. The lowland that borders a stream and is subject to flooding when the stream overflows its banks.

Floodway. A channel (either natural, excavated, or bounded by dikes and levees) used to carry flood flows.

Flow Splitter. An engineered, hydraulic structure designed to divert a percentage of storm water to a treatment practice located outside of the primary channel, direct storm water to a parallel pipe system, or bypass a portion of baseflow around a treatment practice.

Flume. A constructed channel lined with erosion-resistant materials used to convey water on steep grades without erosion.

Foundation Drain. A pipe or series of pipes that collects ground water from the foundation or footing of structures to improve stability.

Freeboard. A vertical distance between the elevation of the design high-water and the top of a dam, diversion ridge, or other water control device.

Full Sedimentation Design. Storm water filter system design involving storage and pretreatment of the entire water quality volume.

Gabion. A wire mesh cage, usually rectangular, filled with rock and used to protect channel banks and other sloping areas from erosion.

Gauge. (1) A device for measuring precipitation, water level, discharge, velocity, pressure, temperature, etc. (2) A measure of the thickness of metal.

Gauging Station. A selected section of a stream channel equipped with a gauge, stage recorder, or other facilities for determining stream stage and discharge.

Geotextile Fabric. A woven or non-woven, water-permeable synthetic material used to trap sediment particles or prevent the clogging of aggregates with fine-grained soil particles.

Geotextile Liner. A synthetic, impermeable fabric used to seal impoundments against leaks.

Grab Strength. A measure of the tensile strength for geotextiles, in elongation, as defined in ASTM-4632.

Gradation. The distribution of the various-sized particles that constitute a sediment, soil, or other material, such as riprap.

Grade. (1) The slope of a road, a channel, or natural ground. (2) The finished surface of a canal bed, roadbed, top of embankment, or bottom of excavation; any surface prepared to a design elevation for the support of construction, such as paving or the laying of a conduit. (3) To finish the surface of a canal bed, roadbed, top of embankment, or bottom of excavation, or other land area to a smooth, even condition.

Grade Stabilization Structure. A structure for the purpose of stabilizing the grade of a gully or other watercourse, thereby preventing further head-cutting or lowering of the channel bottom.

Gradient. (1) A change of elevation, velocity, pressure, or other characteristics per unit length. (2) Slope.

Grading. The cutting/or filling of the land surface to a desired slope or elevation.

Grass. A member of the botanical family Gramineae, characterized by blade-like leaves that originate as a sheath wrapped around the stem.

Grass Drainage Channels. Traditional vegetated open channels, typically trapezoidal, triangular, or parabolic in shape, whose primary function is to provide non-erosive conveyance, typically up to the 10-year frequency design flow. They provide limited pollutant removal through filtration by grass or other vegetation, sedimentation, biological activity in the grass/soil media, as well as limited infiltration if underlying soils are pervious.

Grassed Waterway. A natural or constructed waterway, usually broad and shallow, covered with erosion-resistant grasses and used to safely conduct surface water from an area.

Ground Cover (Horticulture). Low-growing, spreading plants useful for low-maintenance landscape areas.

Ground Water Recharge The process by which water seeps into the ground, eventually replenishing ground water aquifers and surface waters such as lakes, streams, and oceans. This process helps maintain water flow in streams and wetlands and preserves water table levels that support drinking water supplies.

Ground Water Recharge Volume (GRV). The post-development design recharge volume (i.e., on a storm event basis) required to minimize the loss of annual predevelopment ground water recharge. The GRV is determined as a function of annual predevelopment recharge for site-specific soils or surficial materials, average annual rainfall volume, and amount of impervious cover on a site.

Habitat. The environment in which the life needs of a plant or animal are supplied.

Hardware Cloth. A welded wire fabric, typically with square openings of one inch or less.

Head. (1) The height of water above any plane of reference. (2) The energy, either kinetic or potential, possessed by each unit weight of a liquid, expressed as the vertical height through which a unit would have to fall to release the average energy possessed. Used in various compound terms, such as pressure head or velocity head.

Head Loss. Energy loss due to friction, eddies, changes in velocity, elevation, or direction of flow.

Headwater. (1) The source of a stream. (2) The water upstream from a structure or point on a stream.

Heavy Metals. Metals such as copper, zinc, barium, cadmium, lead, and mercury, which are natural constituents of the earth's crust. Heavy metals are stable and persistent environmental contaminants since they cannot be degraded or destroyed.

Hydraulic Conductivity. The rate at which water moves through a saturated porous media under a unit potential-energy gradient. It is a measure of the ease of water movement in soil and is a function of the fluid as well as the porous media through which the fluid is moving.

Hydraulic Head. The kinetic or potential energy of a unit weight of water expressed as the vertical height of water above a reference datum.

Hydrocarbons. Inorganic compounds consisting of carbon and hydrogen, including petroleum hydrocarbons derived from crude oil, natural gas, and coal.

Hydrodynamic Separators. A group of storm water treatment technologies designed to remove large particle total suspended solids and large oil droplets, consisting primarily of cylindrical-shaped devices that are designed to fit in or adjacent to existing storm water drainage systems. The most common mechanism used in these devices is vortex-enhanced sedimentation, where storm water enters as tangential inlet flow into the side of the cylindrical structure. As the storm water spirals through the chamber, the swirling motion causes the sediments to settle by gravity, removing them from the storm water.

Hydrograph. A graph showing for a given point on a stream the discharge, stage (depth), velocity, or other property of water with respect to time.

Hydrologic Cycle. The circuit of water movement from atmosphere to earth back to the atmosphere through various stages or processes, such as precipitation, runoff, infiltration, percolation, storage, evaporation, and transpiration.

Hydrologic Zones. Planting zones that reflect the degree and duration of inundation by water, consisting of a deep water pool, shallow water bench, shoreline fringe, riparian fringe, floodplain terrace, and upland slopes.

Hydrology. The science of the behavior of water in the atmosphere, on the surface of the earth, and underground.

Hydromulching. The process of applying mulch hydraulically in a water medium.

Hydroseeder. The machine/equipment used to disseminate seed hydraulically in a water medium. Mulch, lime, and fertilizer can be incorporated into the sprayed mixture.

Illicit Discharges. Unpermitted discharges to waters of the state that do not consist entirely of storm water or uncontaminated ground water except certain discharges identified in the Indiana Department of Environmental Management Phase II Storm Water General Permit.

Impaired Waters [303(d) List]. Those water bodies not meeting water quality standards. This list of impaired waters within each state is referred to as the "303(d) List" and is prepared pursuant to Section 303(d) of the Federal Clean Water Act.

Impervious. Not allowing infiltration.

Impervious Surfaces. Surfaces that cannot infiltrate rainfall, including rooftops, pavement, sidewalks, and driveways.

Impoundment. Generally, an artificial water storage area, such as a reservoir, pit, dugout, sump, etc.

INDOT. Indiana Department of Transportation. Generally used here to refer to specifications contained in the publication "INDOT Standard Specifications."

Infiltration Practices. Storm water treatment practices designed to capture storm water runoff and infiltrate it into the ground over a period of days, including infiltration trenches and infiltration basins.

Infiltration Rate. A soil characteristic determining or describing the maximum rate at which water can enter the soil under specific conditions.

Inoculum. A culture of microorganisms intentionally introduced into a medium, such as seed, soil, or compost.

Integrated Pest Management (IPM). An approach to pesticide usage that combines monitoring; pest trapping; establishment of action thresholds; use of resistant varieties and cultivars; cultural, physical, and biological controls; and precise timing and application of pesticide treatments to avoid the use of chemical pesticides when possible and use the least toxic pesticide that targets the pest of concern, when pesticide usage is unavoidable.

Intermittent Stream. A stream or a portion of a stream that flows only in direct response to precipitation. It receives little or no water from springs and no long-continued supply from melting snow or other sources. It is dry for a large part of the year, ordinarily more than three months.

Invert. The inside bottom of a culvert or other conduit.

Keyway. A cutoff trench dug beneath the entire length of a dam to cut through soil layers that may cause seepage and possible dam failure.

Lagtime. The interval between the center of mass of the storm precipitation and peak flow of the resultant runoff.

Laminar Flow. Flow at relatively slow velocity in which fluid particles slide smoothly along straight lines everywhere parallel to the axis of a channel or pipe.

Land Capability. The suitability of land for use. Land capability classification involves consideration of: (1) the risks of damage from erosion and other causes and (2) the difficulties in land use owing to physical land characteristics, including climate.

Land Use Controls. Methods for regulating the uses to which a given land area may be put, including such things as zoning, subdivision regulation, and floodplain regulation.

Legume. Any member of the pea or pulse family, which includes peas, beans, peanuts, clover, alfalfa, sweet clover, lespedeza, vetch, black locust, and kudzu. Practically all legumes are nitrogen-fixing plants.

Liquid Limit. The moisture content at which the soil passes from a plastic to a liquid state.

Loam. A soil textural classification in which the proportions of sand, silt, and clay are well balanced. Loams have the best properties for cultivation of plants.

Low Flow Orifice. Principal outlet of a storm water treatment practice to convey flows above the permanent pool elevation.

Low Impact Development (LID). Low impact development is a site design strategy intended to maintain or replicate predevelopment hydrology through the use of small-scale controls integrated throughout the site to manage runoff as close to its source as possible.

Mean Depth. (1) Average depth. (2) Cross-sectional area of a stream or channel divided by its surface or top width.

Mean Velocity. Average velocity of a stream flowing in a channel or conduit at a given cross section or in a given reach. It is equal to the discharge divided by the cross-sectional area of the reach.

Media Filters. These devices consist of media, such as pleated fabric, activated charcoal, perlite, amended sand and perlite mixes, or zeolite placed within filter cartridges that are typically enclosed in concrete vaults. Storm water is passed through the media, which traps particulates and/or soluble pollutants.

Micropool. A smaller permanent pool that is incorporated into the design of a larger storm water pond to avoid resuspension of particles.

Mulch. A natural or artificial layer of plant residue or other materials covering the land surface which conserves moisture, holds soil in place, aids in establishing plant cover, and minimizes temperature fluctuations.

Mullen Burst Test. A standardized test used to test the strength of geotextile fabrics to bursting pressures.

Municipal Separate Storm Sewer System (MS4). Conveyances for storm water including but not limited to roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels or storm drains owned or operated by any municipality, sewer or sewage district, fire district, state agency or federal agency and discharging directly to surface waters of the state.

Native Plants. Plants that are adapted to the local soil and rainfall conditions and that require minimal watering, fertilizer, and pesticide application.

Natural Drainage. The flow patterns of storm water runoff over the land in its predevelopment state.

Nitrate. One of the forms of nitrogen found in aquatic ecosystems. It is produced during nitrification and denitrification by bacteria. Nitrate is the most completely oxidized state of nitrogen commonly found in water, and is the most readily available state utilized for plant growth.

Nitrite. A form of nitrogen that is the end product of nitrification, which is produced by *Nitrobacter spp*. Nitrate is also the initial substrate for denitrification.

Nitrogen Fixation. The conversion of atmospheric nitrogen into stable compounds usable by plants. Carried out by bacteria that colonize the roots of most legumes.

Node (Botany). The point on a plant stem at which a leaf or leaves arise. Creeping stems (i.e., rhizomes and stolons), and in some plants the upright stems, produce roots at the nodes.

Nonpoint Source Pollution. Pollution that enters a waterbody from diffuse origins on the watershed and does not result from discernable, confined, or discrete conveyances.

Non-Routine Maintenance. Corrective measures taken to repair or rehabilitate storm water controls to proper working condition. Non-routine maintenance is performed as needed, typically in response to problems detected during routine maintenance and inspections.

Non-Structural Controls. Pollution control techniques, such as management actions and behavior modification, that do not involve the construction or installation of devices.

Normal Depth. Depth of flow in an open conduit during uniform flow for the given conditions.

Nutrients. (1) A substance necessary for the growth and reproduction of organisms. (2) In water, those substances (chiefly nitrates and phosphates) that promote growth of algae and bacteria.

Oil/Particle Separators. Consist of one or more chambers designed to remove trash and debris and to promote sedimentation of coarse materials and separation of free oil (as opposed to emulsified or dissolved oil) from storm water runoff. Oil/particle separators are typically designed as off-line systems for pretreatment of runoff from small impervious areas and therefore provide minimal attenuation of flow. Also called oil/grit separators, water quality inlets, and oil/water separators.

Open Drain. A natural watercourse or constructed open channel that conveys drainage water.

Open Space Development. A compact form of development that concentrates density in one portion of the site in exchange for reduced density elsewhere. Also known as cluster or conservation development.

Outfall. The point, location, or structure where wastewater or drainage discharges from a sewer to a receiving body of water.

Outlet. The point of water disposal from a stream, river, lake, tidewater, or artificial drain.

Outlet Channel. A waterway constructed or altered primarily to carry water from man-made structures, such as smaller channels, tile lines, and diversions.

Outside Valley. The spacing or width of corrugations for corrugated metal pipe.

Partial Sedimentation Design. Storm water filter system design involving storage and pretreatment of a portion of the water quality volume.

Peak Discharge. The maximum instantaneous flow from a given storm condition at a specific location.

Peak Flow Control. Criteria intended to address increases in the frequency and magnitude of a range of potential flood conditions resulting from development. They include stream channel protection, conveyance protection, peak runoff attenuation, and emergency outlet sizing.

Percolation. The movement of water through soil.

Percolation Rate. The rate, usually expressed as inches per hour or inches per day, at which water moves through the soil profile.

Perennial Stream. A stream that maintains water in its channel throughout the year.

Performance Monitoring. Collection of data on the effectiveness of individual storm water treatment practices.

Permanent (Wet) Pool. An area of a detention basin or flood control project that has a fixed water surface elevation due to a manipulation of the outlet structure.

Permeability (Soil). The quality of a soil that enables water or air to move through it. Usually expressed in inches per hour or inches per day.

Permeability Rate. The rate at which water will move through a saturated soil. Permeability rates are classified as:

Very slow – Less than 0.06 inch/hour

Slow – 0.06 to 0.20 inch/hour

Moderately slow – 0.20 to 0.63 inch/hour

Moderate – 0.63 to 2.0 inch/hour

Moderately rapid – 2.0 to 6.3 inch/hour

Rapid – 6.3 to 20.0 inch/hour

Very rapid – more than 20.0 inch/hour

Permeable Paving Materials. Materials that are alternatives to conventional pavement surfaces and that are designed to increase infiltration and reduce storm water runoff and pollutant loads. Alternative materials include modular concrete paving blocks, modular concrete or plastic lattice, cast-in-place concrete grids, and soil enhancement technologies. Stone, gravel, and other low-tech materials can also be used as alternatives for low traffic applications such as driveways, haul roads, and access roads.

Permittivity. The volumetric flow rate of water per unit cross-sectional area per unit head under laminar flow conditions, in the normal direction generally through a geotextile.

Pervious. Allowing movement of water.

Pesticides. Chemical compounds used for the control of undesirable plants, animals, or insects. The term includes insecticides, herbicides, algicides, rodenticides, nematicides, fungicides and growth regulators.

pH. A numerical measure of hydrogen ion activity, the neutral point being 7.0. All pH values below 7.0 are acid, and all above are alkaline.

Phase II Storm Water. The second phase of the National Pollutant Discharge Elimination System program which specifically targets certain regulated small municipal separate storm sewer system communities and construction activity disturbing between one and five acres of land.

Phosphorus (Available). Inorganic phosphorus that is readily available for plant growth.

Physiographic Region (Province). Large-scale unit of land defined by its climate, geology, and geomorphic history, and therefore uniform in physiography.

Piping. The formation of "pipes" by underground erosion. Water in the soil carries the fine soil particles away, and a series of eroded tubes of tunnels develop. These openings will grow progressively larger and can cause a dam failure.

Plastic Limit. The moisture content at which a soil changes from a semi-solid to a plastic state.

Plasticity Index. The numerical difference between the liquid limit and the plastic limit of soil. The range of moisture content within which the soil remains plastic.

Plunge Pool. A basin used to dissipate the energy of flowing water. Usually constructed to a design depth and shape. The pool may be protected from erosion by various lining materials.

Point Source. Any discernible, confined and discrete conveyance, including but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, vessel or other floating craft from which pollutants are or may be discharged (Public Law 92-500, Section 502[14]).

Porosity. The volume of pore space in soil or rock.

Porous Pavement (Pervious). Porous pavement is similar to conventional asphalt or concrete but is formulated to have more void space for greater water passage through the material.

Pretreatment. Techniques used in storm water management to provide storage and removal of coarse materials, floatables, or other pollutants before the primary treatment practice.

Primary Storm Water Treatment Practice. Storm water treatment practices that are capable of providing high levels of water quality treatment as stand-alone devices; can be grouped into five major categories: storm water ponds, storm water wetlands, infiltration practices, filtering practices, and water quality swales.

Principal Spillway. A dam spillway generally constructed of permanent material and designed to regulate the normal water level, provide flood protection, and/or reduce the frequency of operation of the emergency spillway.

Rain Barrels. Barrels designed to retain small volumes of runoff for reuse for gardening and landscaping. They are applicable to residential, commercial, and industrial sites and can be incorporated into a site's landscaping plan. The size of the rain barrel is a function of rooftop surface area and the design storm to be stored.

Rainfall Intensity. The rate at which rain is falling at any given instant, usually expressed in inches per hour.

Rain Garden. Functional landscape elements that combine plantings in depressions that allow water to pool for only a few days after a rainfall then be slowly absorbed by the soil and plantings.

Rainwater Harvesting. The collection and conveyance of rainwater from roofs and storage in either rain barrels or cisterns. Depending on the type and reuse of the rainwater, purification may be required prior to distribution of the rainwater for reuse. Harvested rainwater can be used to supply water for drinking, washing, irrigation, and landscaping.

Rational Method. A means of computing storm drainage flow rates (Q) by use of the formula Q=CIA, where C is a coefficient describing the physical drainage area, I is the rainfall intensity and A is the area.

Reach. The smallest subdivision of the drainage system, consisting of a uniform length of open channel. Also, a discrete portion of river, stream or creek. For modeling purposes, a reach is somewhat homogeneous in its physical characteristics.

Receiving Stream. The body of water into which runoff or effluent is discharged.

Recharge. Replenishment of ground water reservoirs by infiltration and transmission from the outcrop of an aquifer or from permeable soils.

Recharge Basin. A basin provided to increase infiltration for the purpose of replenishing ground water supplies.

Retention. The storage of storm water to prevent it from leaving the development site. May be temporary or permanent.

Retention Structure. A natural or artificial basin that functions similar to a detention structure except that it maintains a permanent water supply.

Retention (or Residence) Time. The average length of time that a "parcel" of water spends in a storm water pond or other waterbody.

Revetment. Facing of stone or other material, either permanent or temporary, placed along the edge of a stream to stabilize the bank and protect it from the erosive action of the stream. Also see *Riprap.*

Rhizome. A modified plant stem that grows horizontally underground. A rhizomatous plant spreads (reproduces) vegetatively and can be transplanted with rhizome fragments.

Rill. A small intermittent watercourse with steep sides, usually only a few inches deep.

Riparian. Of, on, or pertaining to the banks of a stream, river, or pond.

Riparian Rights. A principle of common law requiring that any user of waters adjoining or flowing through his lands must use and protect them in a manner that will enable his neighbor to utilize the same waters undiminished in quantity and undefiled in quality.

Riprap. Broken rock, cobble, or boulders placed on earth surfaces, such as the face of a dam or the bank of a stream, for protection against the action of water (waves). Revetment riprap is material graded such that (1) no individual piece weighs more than 120 lbs. and (2) 90–100% will pass through a 12-inch sieve, 20–60% through a 6-inch sieve, and not more than 10% through a 1½-inch sieve.

Riser. The inlet portions of a drop inlet spillway that extend vertically from the pipe conduit barrel to the water surface.

Routine Maintenance. Maintenance performed on a regular basis to maintain proper operation and aesthetics.

Runoff. That portion of precipitation that flows from a drainage area on the land surface, in open channels, or in storm water conveyance systems.

Runoff Capture Volume (RCV). The runoff capture volume is equivalent to the water quality volume (WQV) and is the storm water runoff volume generated by the first inch of rainfall on the site.

Safety Bench. A flat area above the permanent pool and surrounding a storm water pond or wetland to provide separation from the pool and adjacent slopes.

Sand. (1) Soil particles between 0.05 mm and 2.0 mm in diameter. (2) A soil textural class inclusive of all soils that are at least 70% sand and 15% or less clay.

Saturation. In soils, the point at which a soil or aquifer will no longer absorb any amount of water without losing an equal amount.

Scour(ing). The clearing and digging action of flowing water, especially the downward erosion caused by stream water in seeping away mud and silt from the stream bed and outside bank of a curved channel.

Seasonally High Ground Water Table. The highest elevation of the ground water table typically observed during the year.

Secondary Storm Water Treatment Practices. Storm water treatment practices that may not be suitable as standalone treatment because they either are not capable of meeting the water quality treatment performance criteria or have not yet received the thorough evaluation needed to demonstrate the capabilities for meeting the performance criteria.

Sediment. 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.

Sediment Chamber or Forebay. An underground chamber or surface impoundment (i.e., forebay) designed to remove sediment and/or floatables prior to a primary or other secondary storm water treatment practice.

Sediment Delivery Ratio. The fraction of the soil eroded from upland sources that actually reaches a stream channel or storage reservoir.

Sediment Discharge. The quantity of sediment, measured in dry weight or by volume, transported through a stream cross section in a given time. Sediment discharge consists of both suspended load and bedload.

Sediment Pool. The reservoir space allotted to the accumulation of sediment during the life of the structure.

Sedimentation. The settling and accumulation of unconsolidated sediment carried by runoff.

Seedbed. Soil prepared by natural or artificial means to promote the germination of seed and the growth of seedlings.

Seedling. A young plant grown from seed.

Settling Basin. An enlargement in the channel of a stream to permit the settling of debris carried in suspension.

Shallow Marsh. The portion of a storm water wetland that consists of aquatic vegetation within a permanent pool ranging in depth from 6 inches to 18 inches during normal conditions.

Shared Parking. A strategy that reduces the number of parking spaces needed by allowing adjacent land uses with different peak parking demands to share parking lots.

Shoot. The aboveground portion of a plant.

Silt. (1) Soil fraction consisting of particles between 0.002 mm and 0.05 mm in diameter. (2) A soil textural class indicating more than 80% silt.

Site Planning and Design. Techniques of engineering and landscape design that maintain predevelopment hydrologic functions and pollutant removal mechanisms to the extent practical.

Site Storm Water Management Plan. Plan describing the potential water quality and quantity impacts associated with a development project both during and after construction. It also identifies selected source controls and treatment practices to address those potential impacts, the engineering design of the treatment practices, and maintenance requirements for proper performance of the selected practices.

Slope. Degree of deviation of a surface from the horizontal measured as a numerical ration or percent. Expressed as a ratio, the first number is the horizontal distance (run) and the second is the vertical distance (rise) (e.g., 2:1). Slope can also be expressed as the rise over the run (e.g., a 2:1 slope is a 50% slope).

Soil. The unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants. Also see *Alluvial Soils, Clay, Cohesive Soil, Loam, Permeability (Soil), Sand, Silt, Soil Horizon, Soil Profile, Subsoil, Surface Soil, and Topsoil.*

Soil and Water Conservation District (SWCD). A public organization created under state law as a special-purpose district to develop and carry out a program of soil, water, and related resource conservation, use, and development within its boundaries. Usually a subdivision of state government with a local governing body but having limited authorities.

Soil Horizon. A horizontal layer of soil that, through processes of soil formation, has developed characteristics distinct from the layers above and below.

Soil Infiltration Capacity. The maximum rate at which water can infiltrate into the soil from the surface.

Soil Profile. A vertical section of the soil from the surface through all horizons.

Soil Structure. The relation of particles that impart to the whole soil a characteristic manner of breaking (e.g., crumb, block, platy, or columnar structure).

Soil Texture. The physical structure or character of soil determined by the relative proportions of the soil separates (sand, silt, and clay) of which it is composed.

Soluble Phosphorus. Soluble phosphorus is present predominantly as the ionic species orthophosphate and is thought to be the form readily taken up by plants (i.e., "bioavailable").

Source Controls. Practices to limit the generation of storm water pollutants at their source.

Specific Gravity. The ratio of (1) the weight in air of a given volume of soil solids at a stated temperature to (2) the weight in air of an equal volume of distilled water at a stated temperature.

Spillway. (1) A passage, such as a paved apron or channel, for surplus water to flow over, around, or through a dam or similar structure. (2) An open or closed channel, or both, used to convey excess water from a reservoir. It may contain gates, either manually or automatically controlled, to regulate the discharge of excess water. Also see *Emergency Spillway, Principal Spillway.*

Sprig. Section of plant stem material (rhizome, shoot, or stolon) used in vegetative planting.

Stolon. Mocified plant stem that grows horizontally on the soil surface.

Storm Event. An estimate of the expected amount of precipitation within a given period of time. For example, a 10-year frequency, 24-hour duration storm event is a storm that has a 10% probability of occurring in any one year. Precipitation is measured over a 24-hour period.

Storm Frequency. The time interval between major storms of predetermined intensity and volumes of runoff (e.g., a 5-year, 10-year or 20-year storm).

Storm Sewer. A sewer that carries storm water, surface drainage, street wash, and other wash waters but excludes sewage and industrial wastes. Also called a storm drain.

Storm Water Hotspots. Land uses or activities with potential for higher pollutant loads.

Storm Water Pollution Prevention Plan (SWPPP). Identifies potential sources of pollution and outlines specific management activities designed to minimize the introduction of pollutants into storm water.

Storm Water Ponds. Vegetated ponds that retain a permanent pool of water and are constructed to provide both treatment and attenuation of storm water flows.

Storm Water Retrofits. Modifications to existing development to incorporate source controls and structural storm water treatment practices to remedy problems associated with, and improve water quality mitigation functions of, older, poorly designed, or poorly maintained storm water management systems.

Storm Water Treatment Practices. Devices constructed for primary treatment, pretreatment or supplemental treatment of storm water.

Storm Water Treatment Train. Storm water treatment practices, as well as site planning techniques and source controls, combined in series to enhance pollutant removal or achieve multiple storm water objectives.

Storm Water Wetlands. Shallow, constructed pools that capture storm water and allow for the growth of characteristic wetland vegetation.

Stream. See *Intermittent Stream, Perennial Stream, Receiving Stream.*

Stream Gauging. The quantitative determination of stream flow using gauges, current meters, weirs, or other measuring instruments at selected locations (see *Gauging Station*).

Streambanks. The usual boundaries (not the flood boundaries) of a stream channel. Right and left banks are named facing downstream.

Street Sweepers. Equipment to remove particulate debris from roadways and parking lots, including mechanical broom sweepers, vacuum sweepers, regenerative air sweepers and dry vacuum sweepers.

Structural Controls. Devices constructed for temporary storage and treatment of storm water runoff.

Submerged Aquatic Vegetation (SAV). Includes rooted, vascular, flowering plants that live permanently submerged below the water in coastal, tidal and navigable waters.

Subsoil. The B horizons of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below which roots do not normally grow.

Subsurface Drain. A pervious backfilled trench, usually containing stone and perforated pipe, for intercepting ground water or seepage.

Subwatershed. A watershed subdivision of unspecified size that forms a convenient natural unit.

Surface Runoff. Precipitation that flows onto the surfaces of roofs, streets, the ground, etc. and is not absorbed or retained by that surface but collects and runs off.

Surface Soil. The uppermost part of the soil ordinarily moved in tillage or its equivalent in an uncultivated soil. Frequently referred to as the plow layer, the Ap layer, or the Ap horizon. Surface soil is usually darker in color due to the presence of organic matter.

Suspended Solids. Solids either floating or suspended in water or sewage and other liquid wastes.

Swale. An elongated depression in the land surface that is at least seasonally wet, is usually heavily vegetated, and is normally without flowing water. Swales conduct storm water into primary drainage channels and may provide some ground water recharge.

Tackifier. An adhesive material sprayed on top of mulch to hold it in place.

Tailwater Depth. The depth of flow immediately downstream from a discharge structure.

Technical Release Number 55 (TR-55). A watershed hydrology model developed by the Soil Conservation Service (now Natural Resources Conservation Service) that is used to calculate runoff volumes, peak flows, and simplified routing for storm events through ponds.

Tile Drain. Pipe made of perforated plastic, burned clay, concrete, or similar material, laid to a designed grade and depth, to collect and carry excess water from the soil.

Tile Drainage. Land drainage by means of a series of tile lines laid at a specified depth, grade, and spacing.

Time of Concentration. The time required for water to flow from the most distant point to the downstream outlet of a site. Runoff flow paths, ground surface slope and roughness, and channel characteristics affect the time of concentration.

Toe of Dam. The base or bottom of the sloping faces of a constructed dam at the point of intersection with the natural ground surface—normally a much flatter slope. A dam has an inside toe (the impoundment or upstream side) and an outside toe (the downstream side).

Toe of Slope. The base or bottom of a slope at the point where the ground surface abruptly changes to a significantly flatter grade.

Topography. A general term to include characteristics of the ground surface, such as plains, hills, mountains, relief, slopes, and other physiographic features.

Topsoil. (1) The dark-colored surface layer, or A horizon, of a soil; when present it ranges in depth from a fraction of an inch to 2-3 feet. (2) Equivalent to the plow layer of cultivated soils. (3) Commonly used to refer to the surface layer(s) enriched in organic matter and having textural and structural characteristics favorable for plant growth.

Total Maximum Daily Load (TMDL). A calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources, including a margin of safety.

Total Organic Carbon. A measure of the organic matter content. The amount of organic matter content affects biogeochemical processes, nutrient cycling, biological availability, chemical transport and interactions, and also has direct implications in the planning of wastewater treatment and drinking water treatment.

Total Phosphorus. Sum of orthophosphate, metaphosphate (or polyphosphate) and organically bound phosphate. Phosphorus is typically the growth-limiting nutrient in freshwater systems.

Total Suspended Solids. The total amount of particulate matter that is suspended in the water column.

Toxicity. The characteristic of being poisonous or harmful to plant or animal life. The relative degree or severity of this characteristic.

Trap Efficiency. The capability of a reservoir to trap sediment.

Trash Rack. A structural device used to prevent debris from entering a pipe spillway or other hydraulic structure

Turbidity. (1) Cloudiness of a liquid, caused by suspended solids. (2) A measure of the suspended solids in a liquid.

Turf. Surface soil supporting a dense growth of grass and associated root mat.

Ultraviolet Radiation Stability. Resistance to degradation from ultraviolet rays. Most synthetic fabrics and plastics without special treatment will quickly lose strength when exposed to sunlight.

Underground Detention Facilities. Vaults, pipes, tanks, and other subsurface structures designed to temporarily store storm water runoff for water quantity control and to drain completely between runoff events. They are intended to control peak flows, limit downstream flooding, and provide some channel protection.

Underground Infiltration Systems. Structures designed to capture, temporarily store, and infiltrate the water quantity volume over several days, including premanufactured pipes, vaults, and modular structures. Used as alternatives to infiltration trenches and basins for space-limited sites and storm water retrofit applications.

Unified Soil Classification System (USCS). A system of classifying soils that is based on their identification according to particle size, gradation, plasticity index, and liquid limit.

Uniform Flow. A state of steady flow when the mean velocity and cross-sectional area remain constant in all sections of a reach.

Urban Storm Water Runoff. Storm water runoff from developed areas.

Vegetated Buffer. An area or strip of land in permanent undisturbed vegetation adjacent to a waterbody or other resource that is designed to protect resources from adjacent development during construction and after development by filtering pollutants in runoff, protecting water quality and temperature, providing wildlife habitat, screening structures and enhancing aesthetics, and providing access for recreation.

Vegetated Filter Strips and Level Spreaders. Uniformly graded vegetated surfaces (i.e., grass or close-growing native vegetation) located between pollutant source areas and downstream receiving waters or wetlands. A level spreader is usually located at the top of the slope to distribute overland flow or concentrated runoff evenly across the entire length of the filter strip.

Vegetated Roof Covers. Multilayered, constructed roof systems consisting of a vegetative layer, media, a geotextile layer, and a synthetic drain layer installed on building rooftops. Rainwater is either intercepted by vegetation and evaporated to the atmosphere or retained in the substrate before being returned to the atmosphere through transpiration and evaporation. Also referred to as green roofs.

Vegetative Stabilization. Protection of erodible or sediment producing areas with: *permanent seeding* (producing long-term vegetative cover), *short-term seeding* (producing temporary vegetative cover), or *sodding* (producing areas covered with a turf of perennial sod-forming grass).

Water Balance. Equation describing the input, output, and storage of water in a watershed or other hydrologic system.

Water Quality. A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

Water Quality Flow (WQF). The peak flow associated with the water quality volume calculated using the Natural Resources Conservation Service graphical peak discharge method.

Water Quality Swales. Vegetated open channels designed to treat and attenuate the water quality volume and convey excess storm water runoff. Dry swales are primarily designed to receive drainage from small impervious areas and rural roads. Wet swales are primarily used for highway runoff, small parking lots, rooftops, and pervious areas.

Water Quality Volume (WQV). The volume of runoff generated by one inch of rainfall on a site.

Water Resources. The supply of ground water and surface water in a given area.

Water Table. (1) The free surface of the ground water. (2) That surface subject to atmospheric pressure under the ground, generally rising and falling with the season or from other conditions such as water withdrawal.

Watercourse. A definite channel with bed and banks within which concentrated water flows, either continuously or intermittently.

Watershed. The region drained by or contributing water to a stream, lake, or other body of water.

Watershed Area. All land and water within the confines of a drainage divide.

Watershed Management. Integrated approach addressing all aspects of water quality and related natural resource management, including pollution prevention and source control.

Weep Holes (Engineering). Openings left in retaining walls, aprons, linings, or foundations to permit drainage and reduce pressure.

Weir. Device for measuring or regulating the flow of water.

Weir Notch. The opening in a weir for the passage of water.

Windthrow. (1) Uprooted by the wind. (2) A tree or trees so uprooted.

Zoning Ordinance. An ordinance based on the police power of government to protect the public health, safety, and general welfare. It may regulate the type of use and the intensity of development of land and structures to the extent necessary for a public purpose. Requirements may vary among geographically defined areas ("zones"). Regulations generally cover such items as height and bulk of buildings, density of dwelling units, off-street parking, control of signs, and use of land for residential, commercial, industrial or agricultural purposes. A zoning ordinance is one of the major methods for implementation of a comprehensive plan.

APPENDIX B — WORKSHEETS & EXHIBITS

A **worksheet** provides the designer a representation of a measure that allows for input of specific design criteria. The plan designer will be required to assess field conditions and apply engineering principles to determine dimensions and specifications. An **exhibit** is a representative view of a measure. An exhibit often includes standardized dimensions and specifications. Several exhibits are only a representative view of the measure, and will require the designer to assess field conditions and input dimensions and specifications for the measure. These exhibits have been identified with a note.

Worksheet	Page

Exhibit	Page

Exhibit	Page

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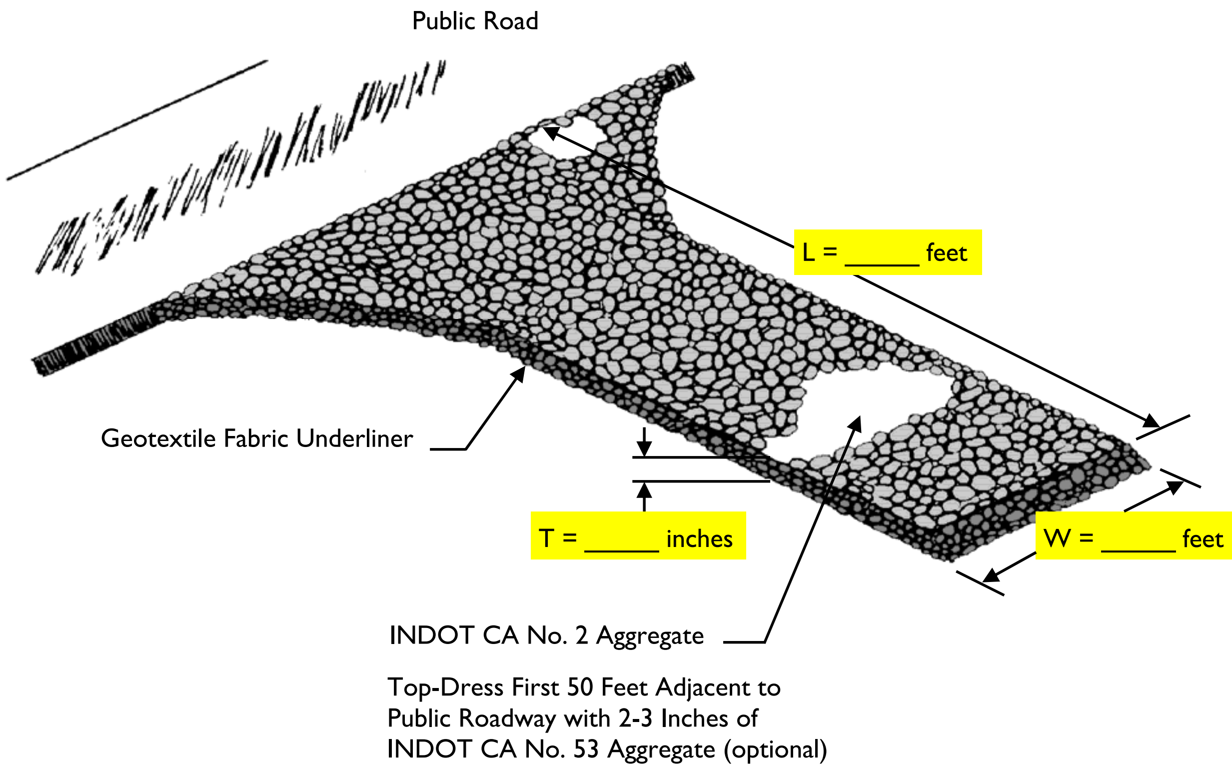
Temporary Construction Ingress/Egress Pad
Plan View Worksheet
(large sites—two acres or larger)



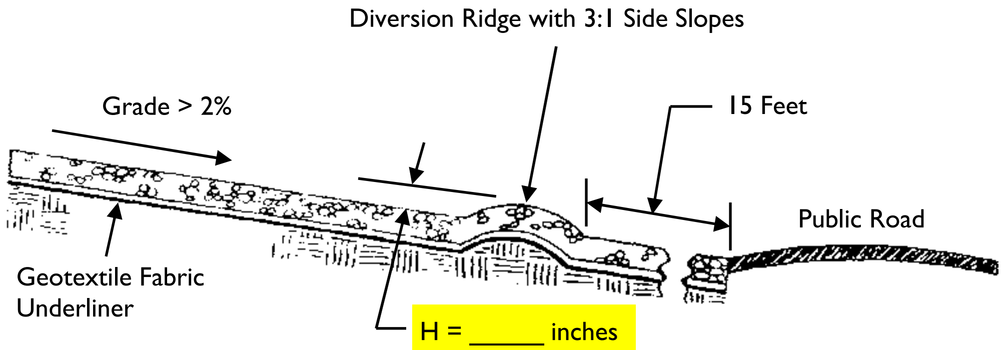
L = Ingress/Egress Pad Length
W = Ingress/Egress Pad Width
T = Aggregate Thickness

(Note: For minimum dimensions, see the "Specifications" section of this measure.)

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

For information on this measure, see Chapter 7, page 17

Temporary Construction Ingress/Egress Pad
Cross-Section View Worksheet
(large sites two acres or larger)



H = Height of Diversion Ridge
(Note: 8 inches minimum)

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

For information on this measure, see Chapter 7, page 17

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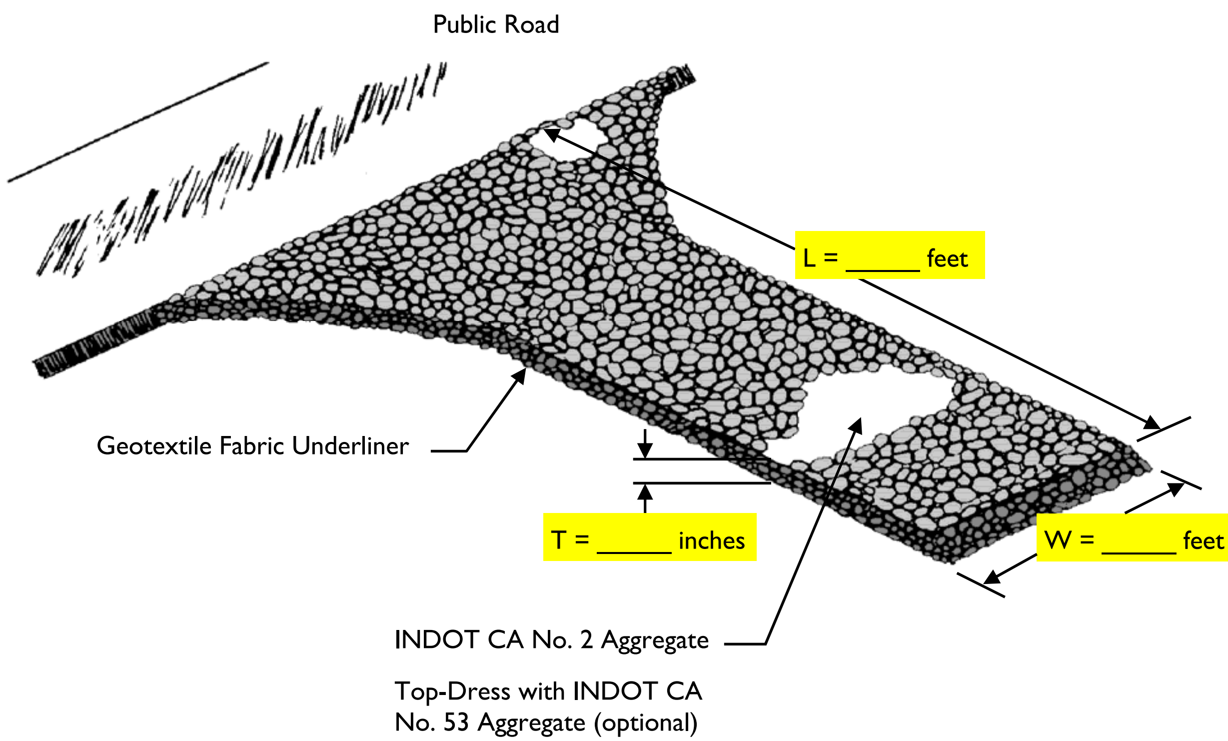
Temporary Construction Ingress/Egress Pad Plan View Worksheet (small sites—less than two acres)



L = Ingress/Egress Pad Length
W = Ingress/Egress Pad Width
T = Aggregate Thickness

(Note: For minimum dimensions, see the "Specifications" section of this measure.)

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

For information on this measure, see Chapter 7, page 21

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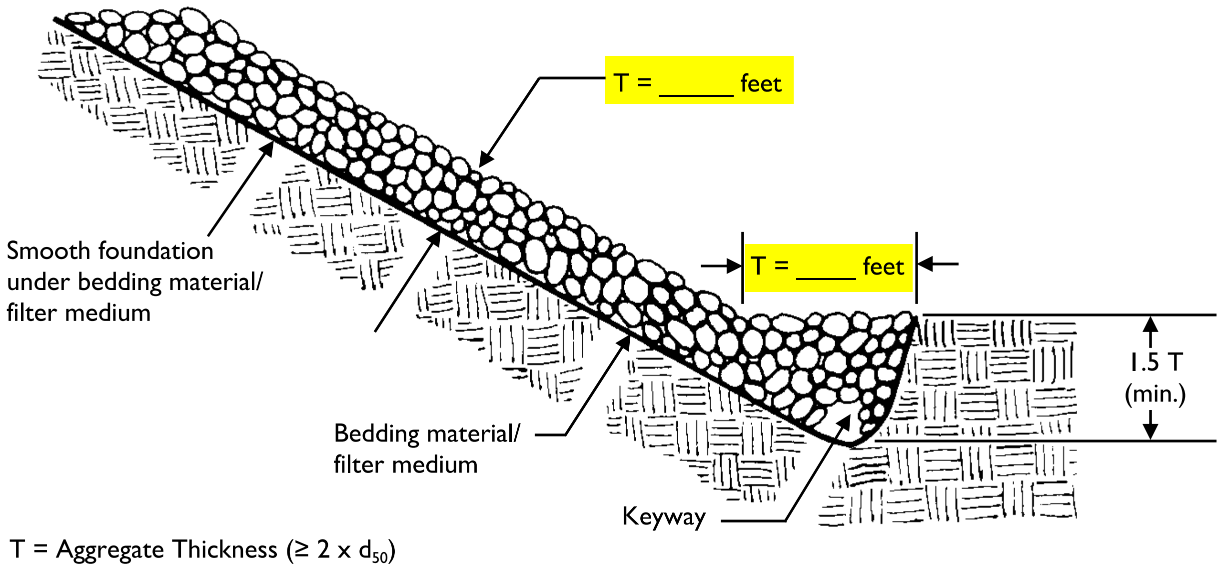
Riprap Slope Protection Worksheet



Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

For information on this measure, see Chapter 7, page 69

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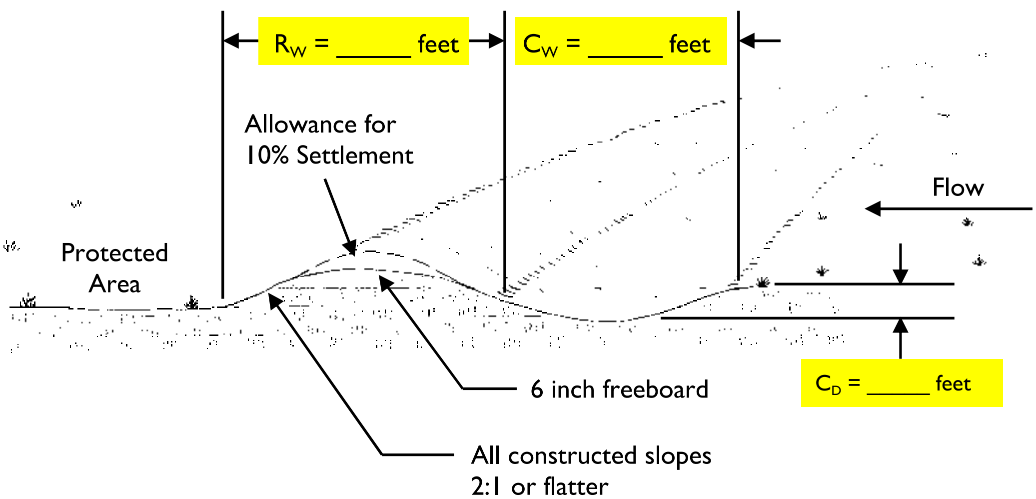
Temporary Diversion Worksheet



C_D = Channel Depth

C_W = Channel Width

R_W = Ridge Width

For information on this measure, see Chapter 7, page 75

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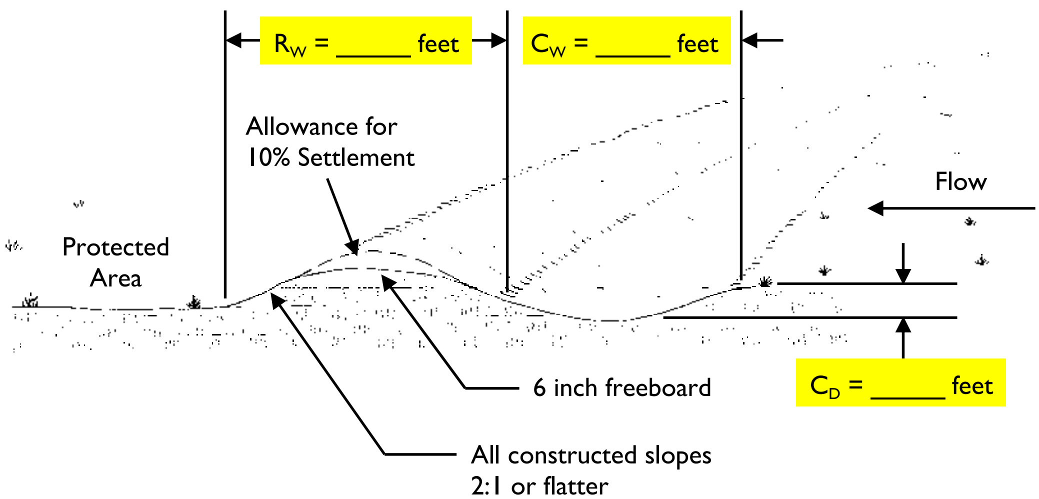
Permanent Diversion Worksheet



C_D = Channel Depth

C_W = Channel Width

R_W = Ridge Width

For information on this measure, see Chapter 7, page 79

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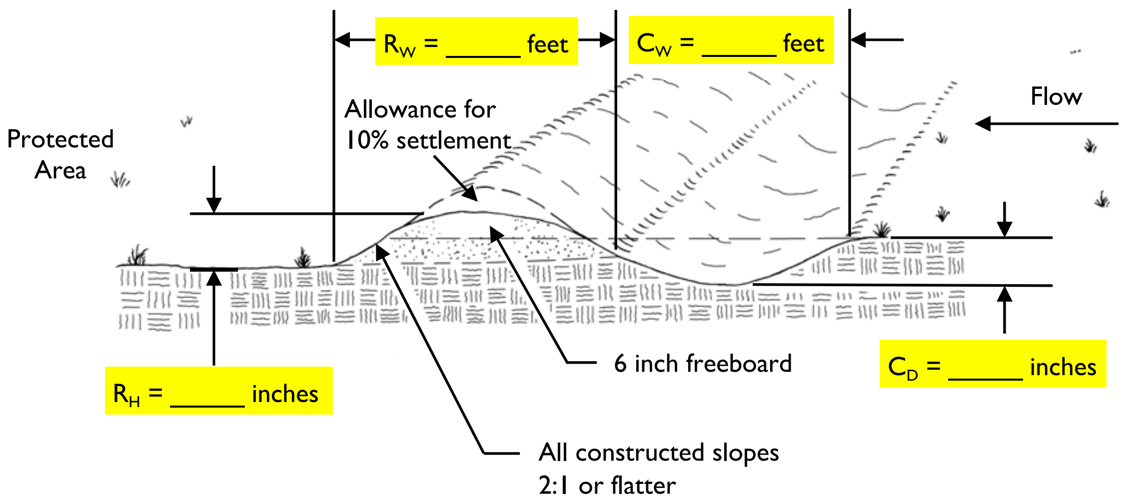
Perimeter Diversion Dike Worksheet



R_H = Ridge Height

R_W = Ridge Base Width

C_D = Channel Depth

C_W = Channel Top Width

Note: Drainage channel is optional.

For information on this measure, see Chapter 7, page 83

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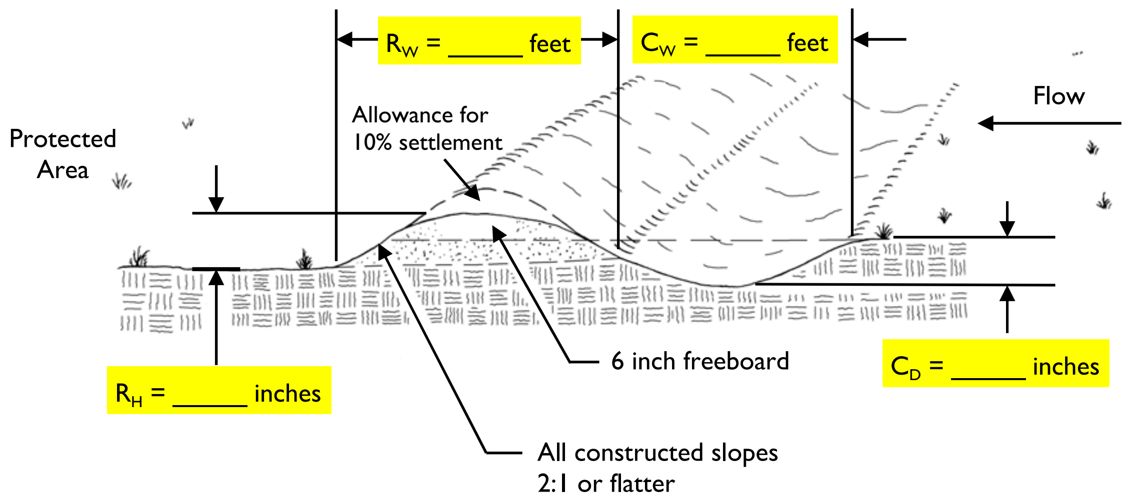
Water Bar Worksheet



R_H = Ridge Height

R_W = Ridge Base Width

C_D = Channel Depth

C_W = Channel Top Width

Note: Drainage channel is optional.

For information on this measure, see Chapter 7, page 89

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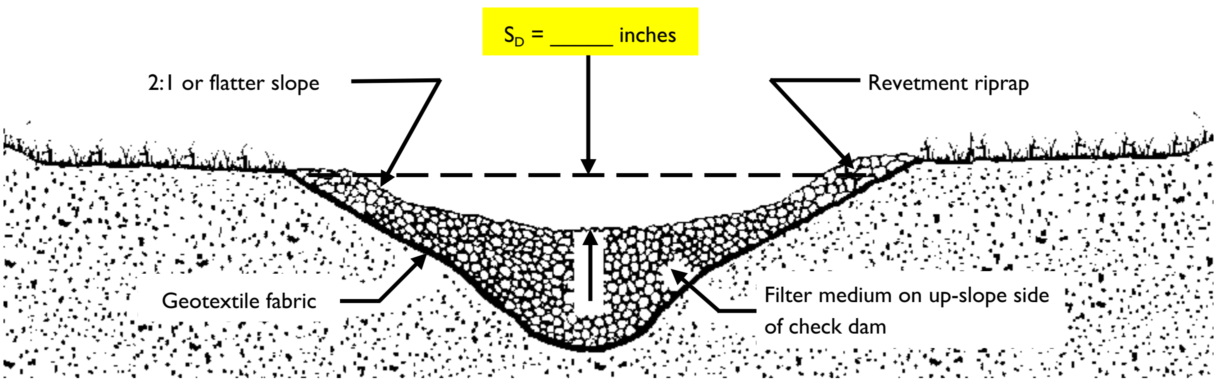
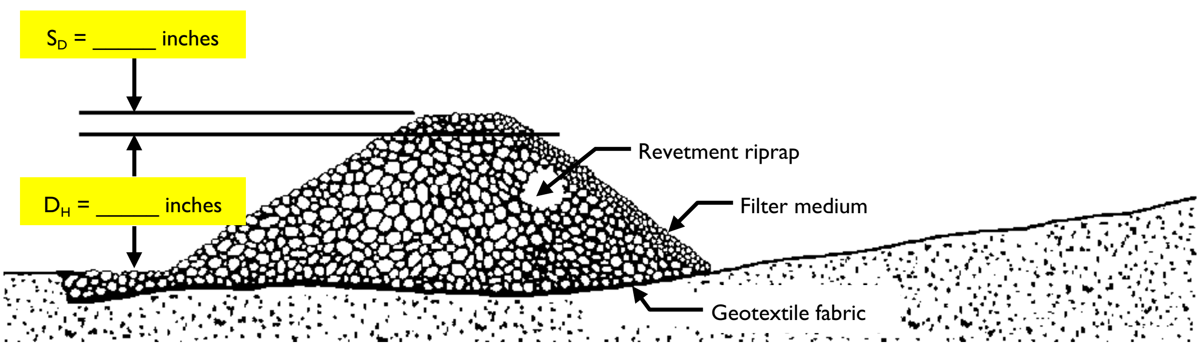
Rock Check Dam Worksheet



S_D = Spillway Depth

(NOTE: For minimum dimensions see the "Specifications" section of this measure.)



D_H = Dam Height

S_D = Spillway Depth

(NOTE: For minimum dimensions see the "Specifications" section of this measure.)

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

For information on this measure, see Chapter 7, page 97

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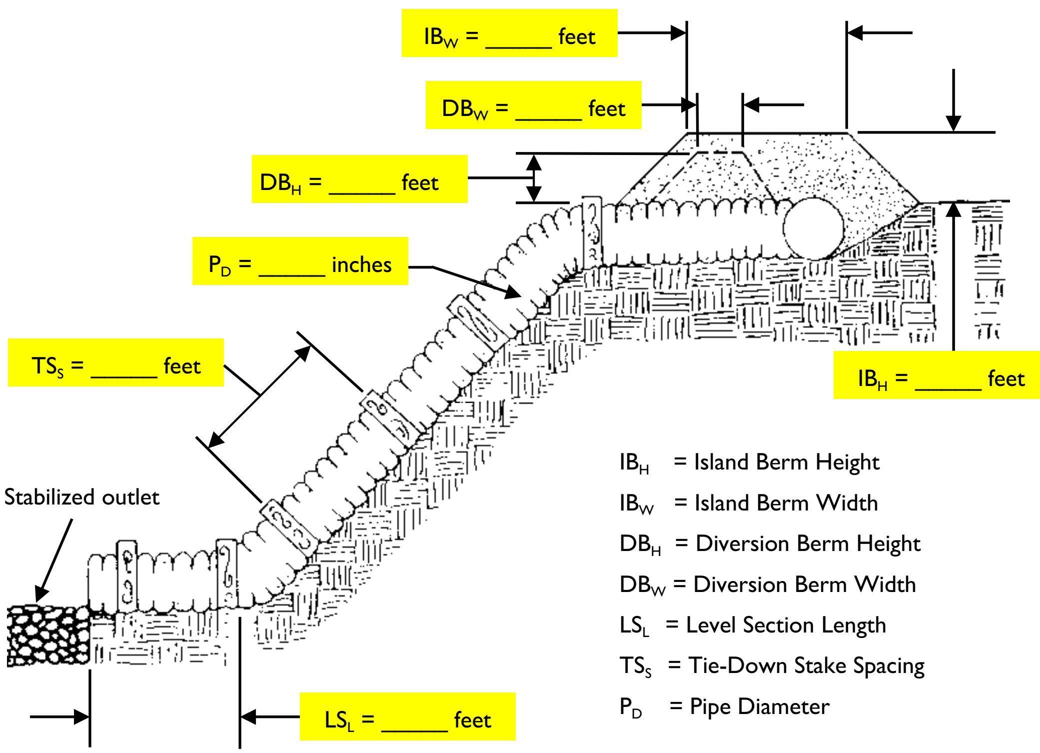
Temporary Slope Drain Worksheet



(Note: For minimum and maximum dimensions, see the "Specifications" section of this measure.)

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

For information on this measure, see Chapter 7, page 103

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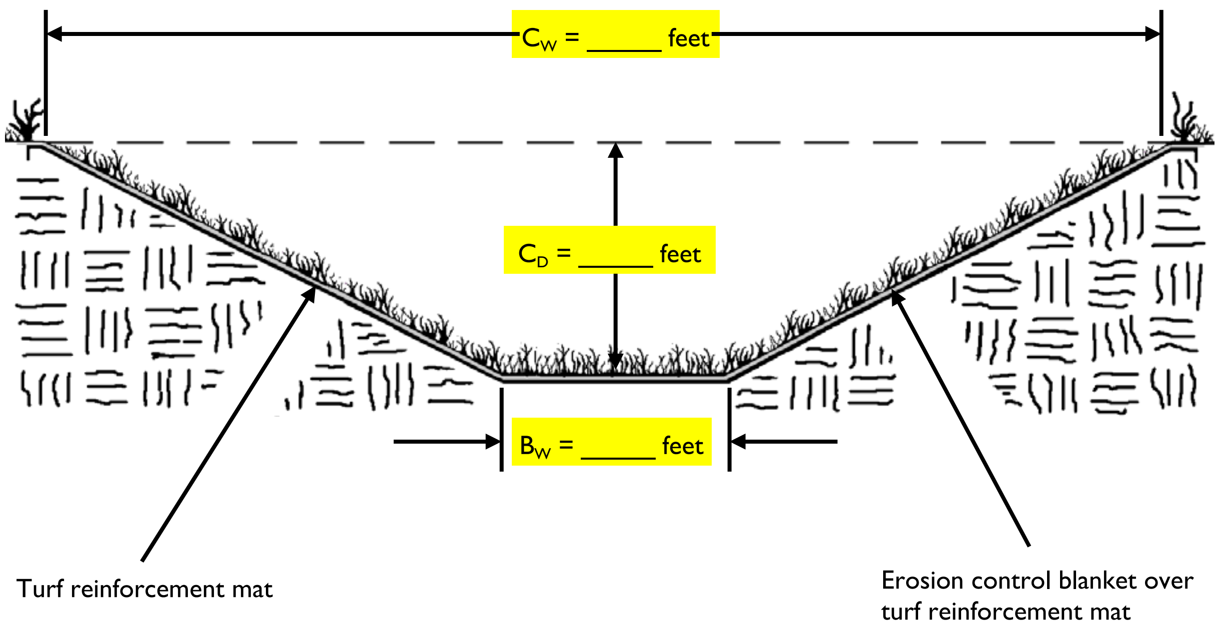
Grass-Lined Channel Worksheet



B_W = Designed Bottom Width of Channel
C_W = Designed Top Width of Channel
C_D = Designed Depth of Channel

For information on this measure, see Chapter 7, page 111

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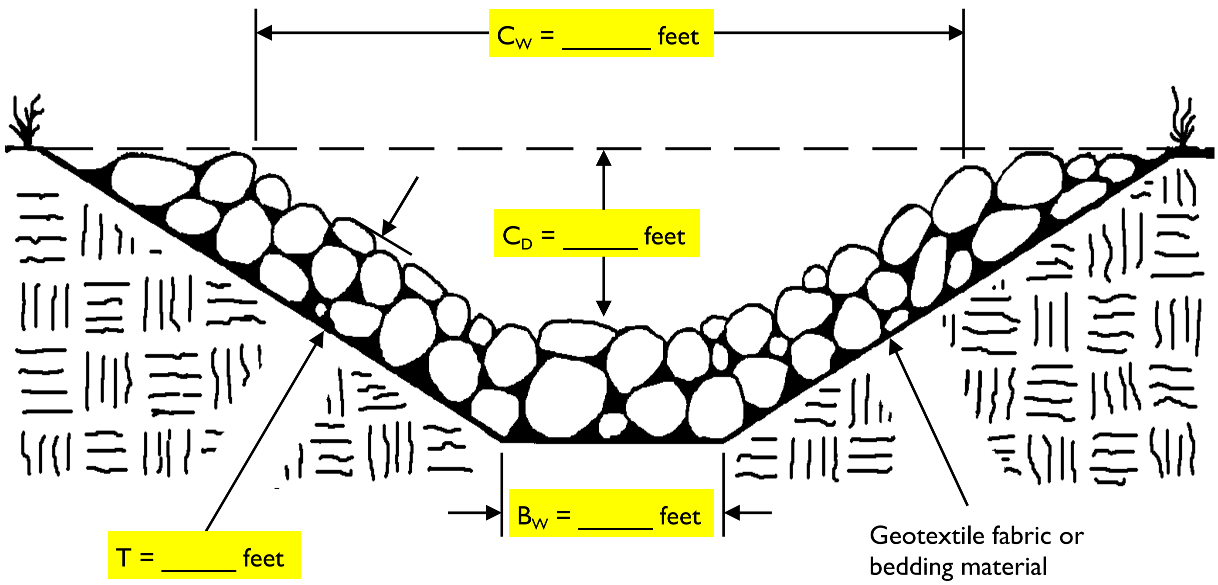
Riprap-Lined Channel Worksheet



B_W = Designed Bottom Width of Channel

C_W = Designed Top Width of Channel

C_D = Designed Depth of Channel

T = Thickness of Riprap Layer

For information on this measure, see Chapter 7, page 115

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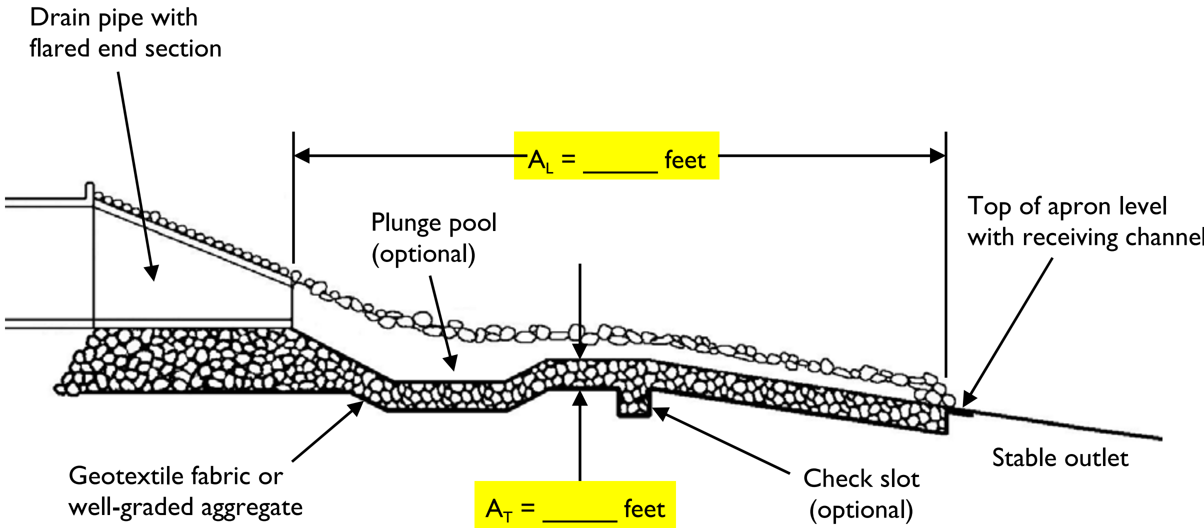
Energy Dissipater Worksheet 1



A_L = Apron Length

A_T = Apron Thickness

For information on this measure, see Chapter 7, page 121

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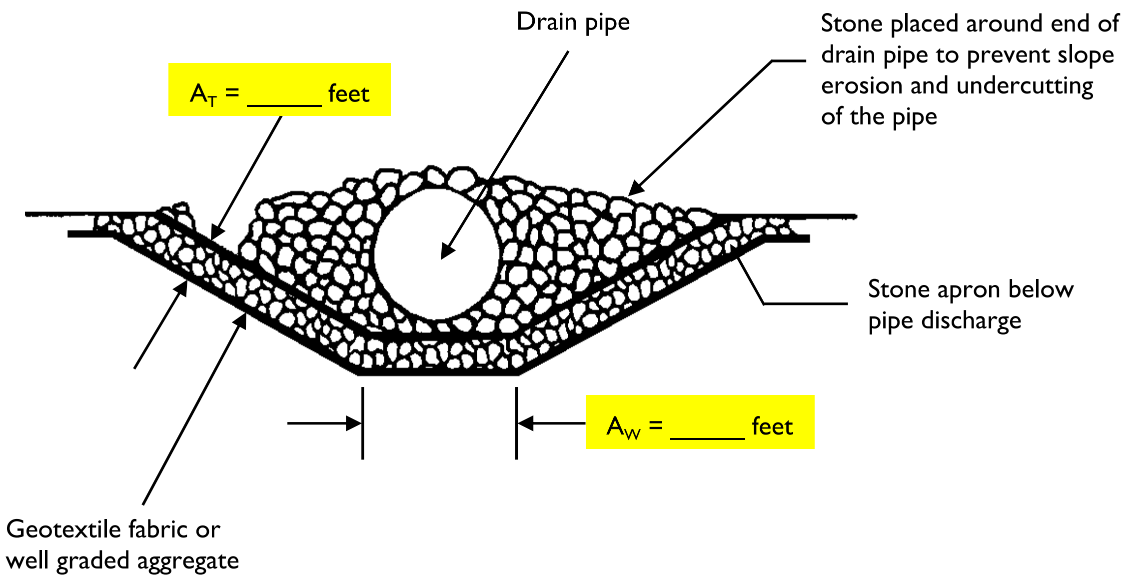
Energy Dissipater Worksheet 2



A_T = Apron Thickness
A_W = Apron Width

Note: A_W is the apron width at the narrow end of the apron.

For information on this measure, see Chapter 7, page 121

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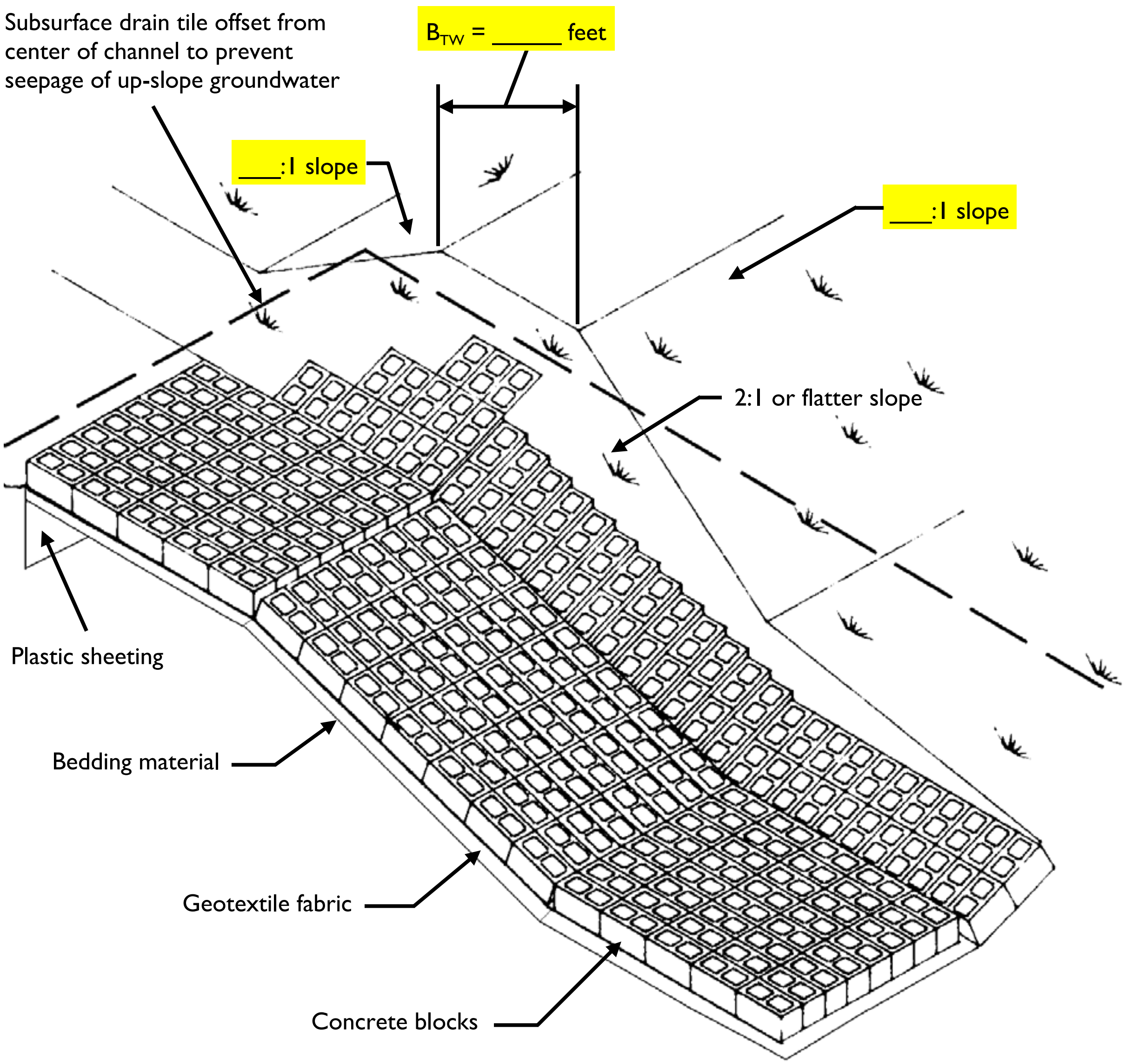
Concrete Block Chute Worksheet



B_{TW} = Berm Top Width

Source: Adapted from U.S. Department of Agriculture, Natural Resources Conservation Service

For information on this measure, see Chapter 7, page 131

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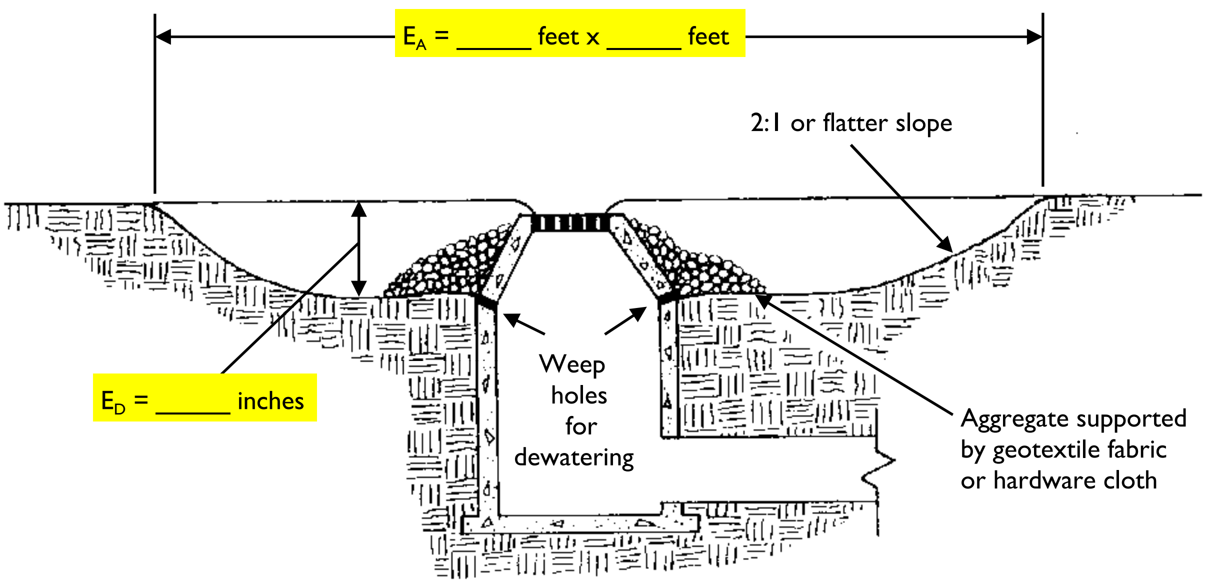
Excavated Drop Inlet Protection Worksheet



E_A = Excavated Area (as required)

E_D = Excavated Depth

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

For information on this measure, see Chapter 7, page 145

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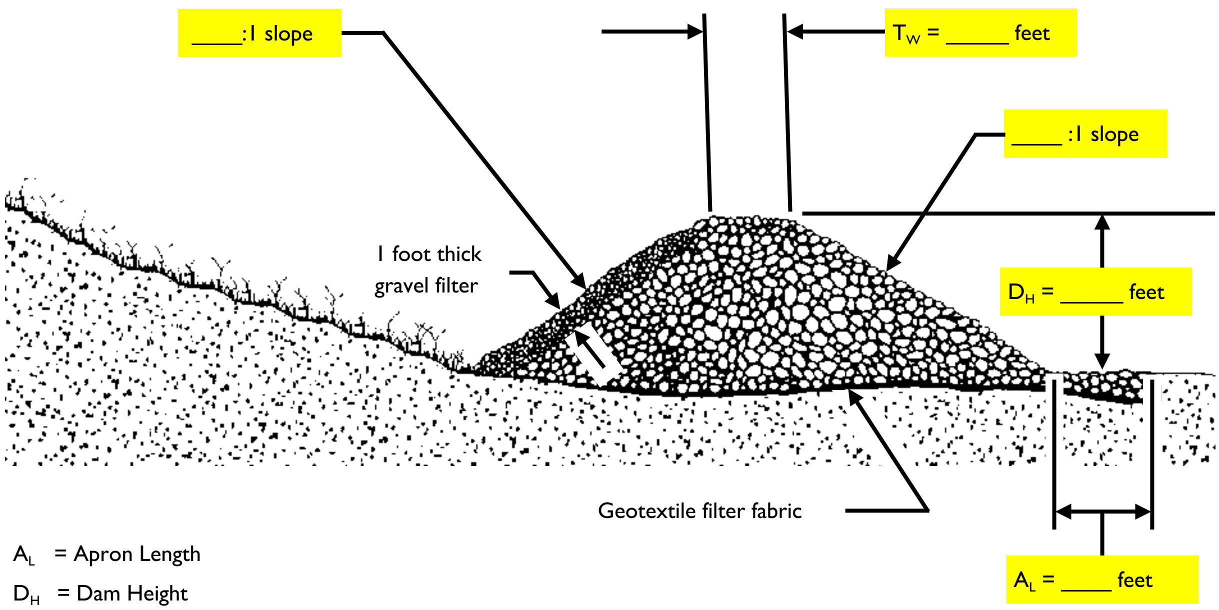
Temporary Sediment Trap
Rock Dam Worksheet



A_L = Apron Length
D_H = Dam Height
FP_E = Flood Pool Elevation
S_D = Spillway Depth
T_W = Top Width

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

For information on this measure, see Chapter 7, page 183

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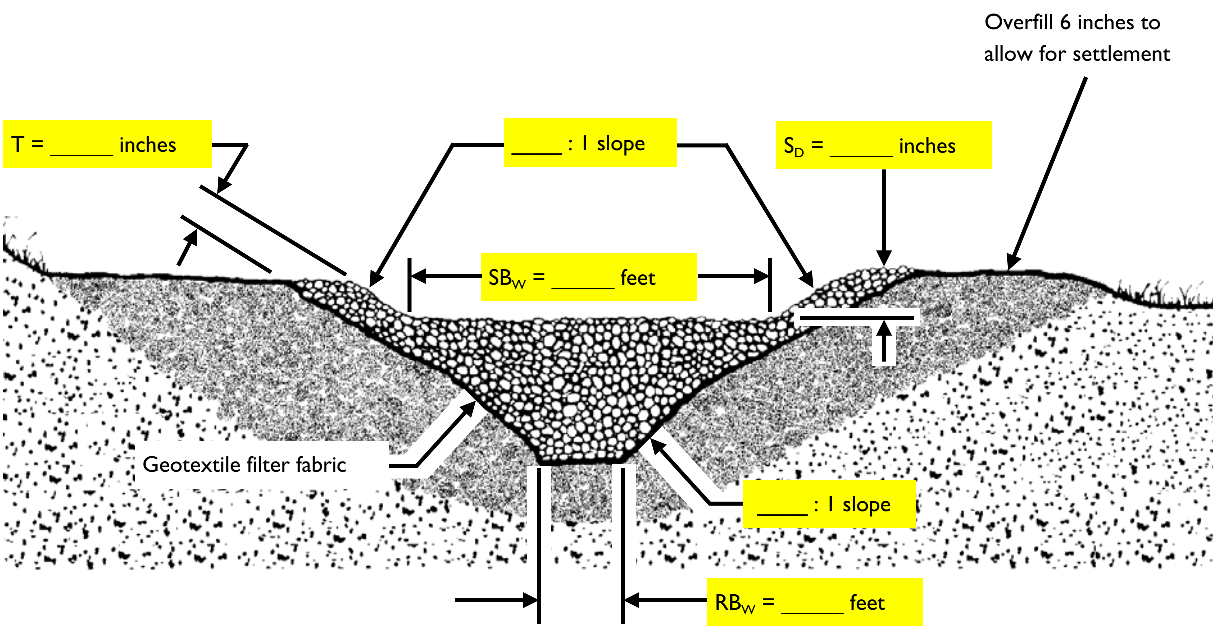
Temporary Sediment Trap
Outlet Worksheet



RB_W = Rock Dam Bottom Width

S_D = Spillway Depth

SB_W = Spillway Bottom Width

T = Spillway Side-Slope Armament Thickness

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

For information on this measure, see Chapter 7, page 183

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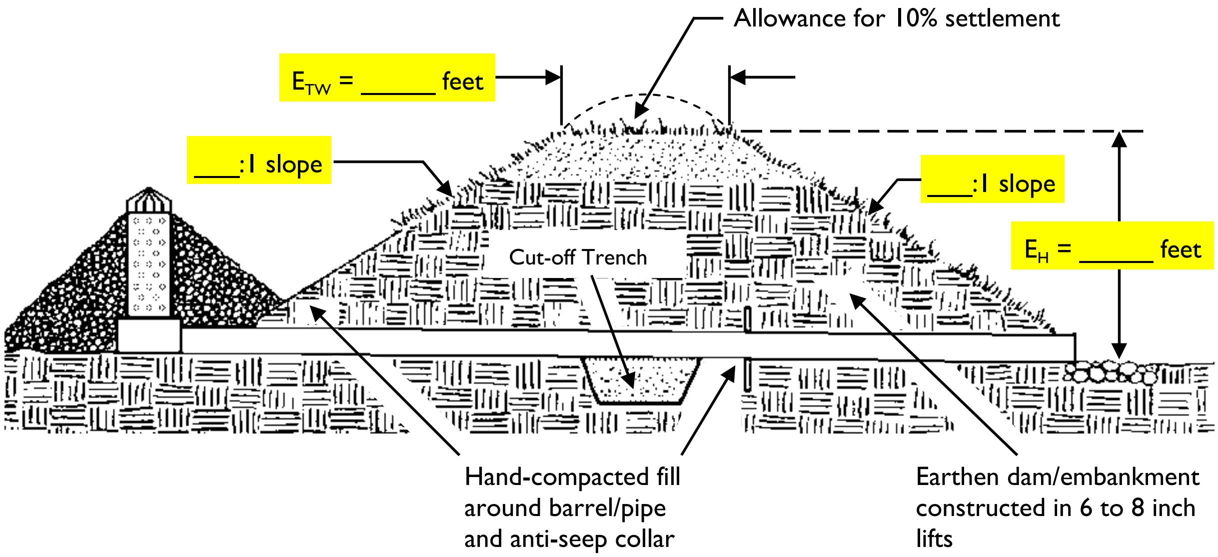
Temporary Dry Sediment Basin
Earthen Dam/Embankment Worksheet



E_H = Earthen Dam/Embankment Height
E_{TW} = Earthen Dam/Embankment Top Width

(NOTE: For minimum dimensions see the "Specifications" section of this measure.)

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

For information on this measure, see Chapter 7, page 191

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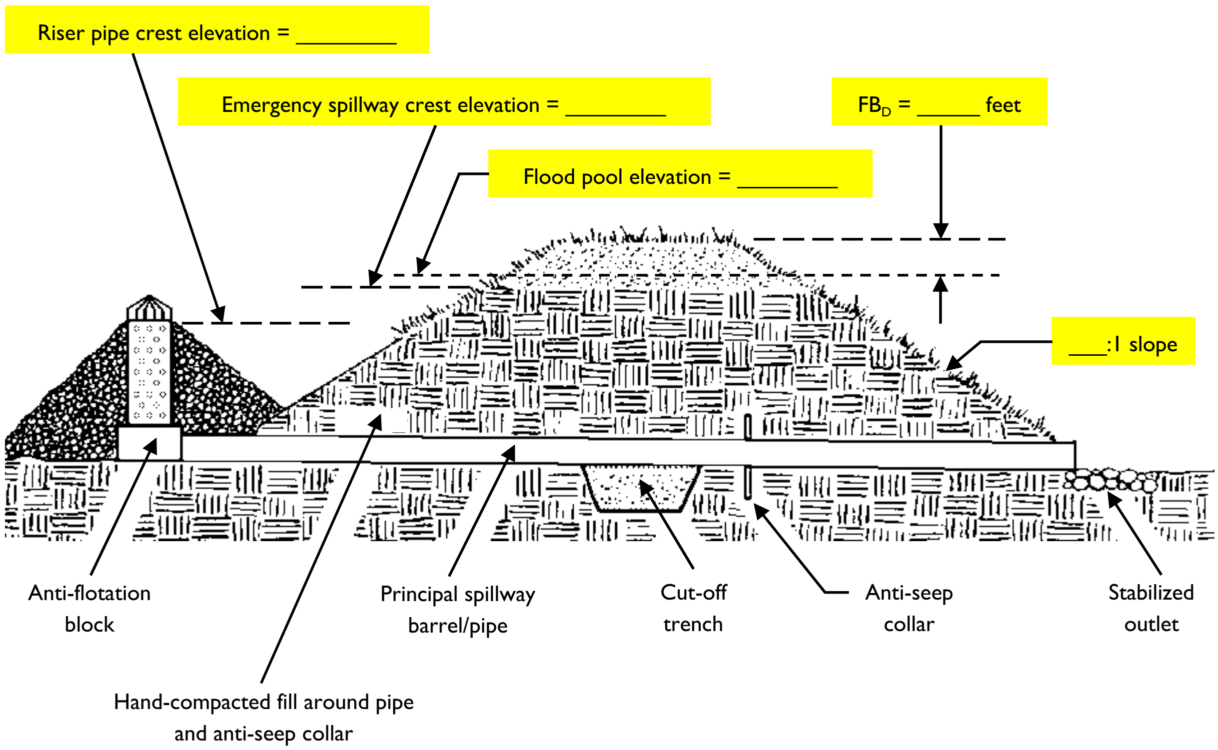
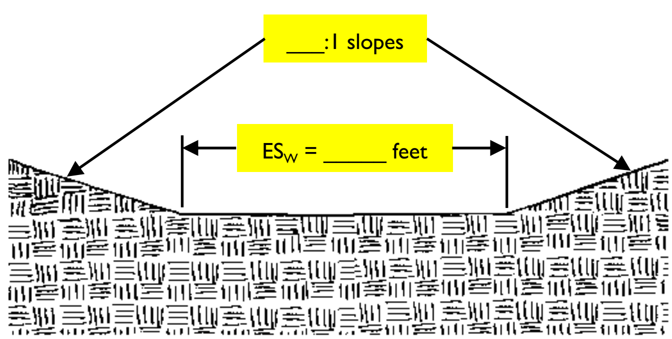
Temporay Dry Sediment Basin
Spillway Worksheet 1



Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993



ES_W = Emergency Spillway Width

FB_D = Free Board Depth

(NOTE: For minimum dimensions see the "Specifications" section of this measure.)

Source: Adapted from U.S. Department of Agriculture, Natural Resources Conservation Service

For information on this measure, see Chapter 7, page 191

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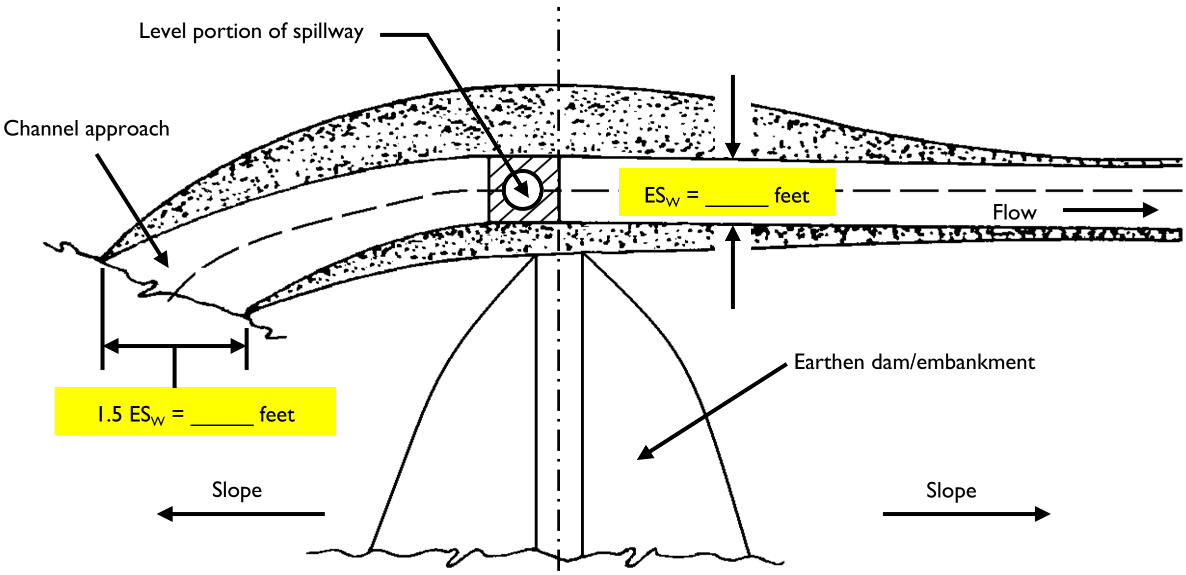
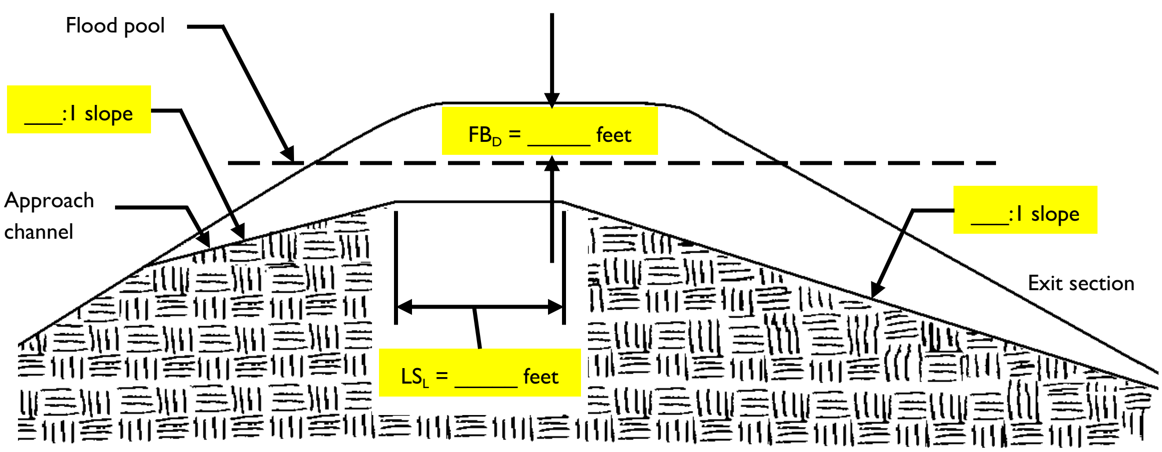
Temporary Dry Sediment Basin
Spillway Worksheet 2





ES_W = Emergency Spillway Width

FB_D = Free Board Depth

LS_L = Level Section Length

(NOTE: For minimum dimensions see the "Specifications" section of this measure.)

For information on this measure, see Chapter 7, page 191

Source: Adapted from USDA Natural Resources Conservation Service

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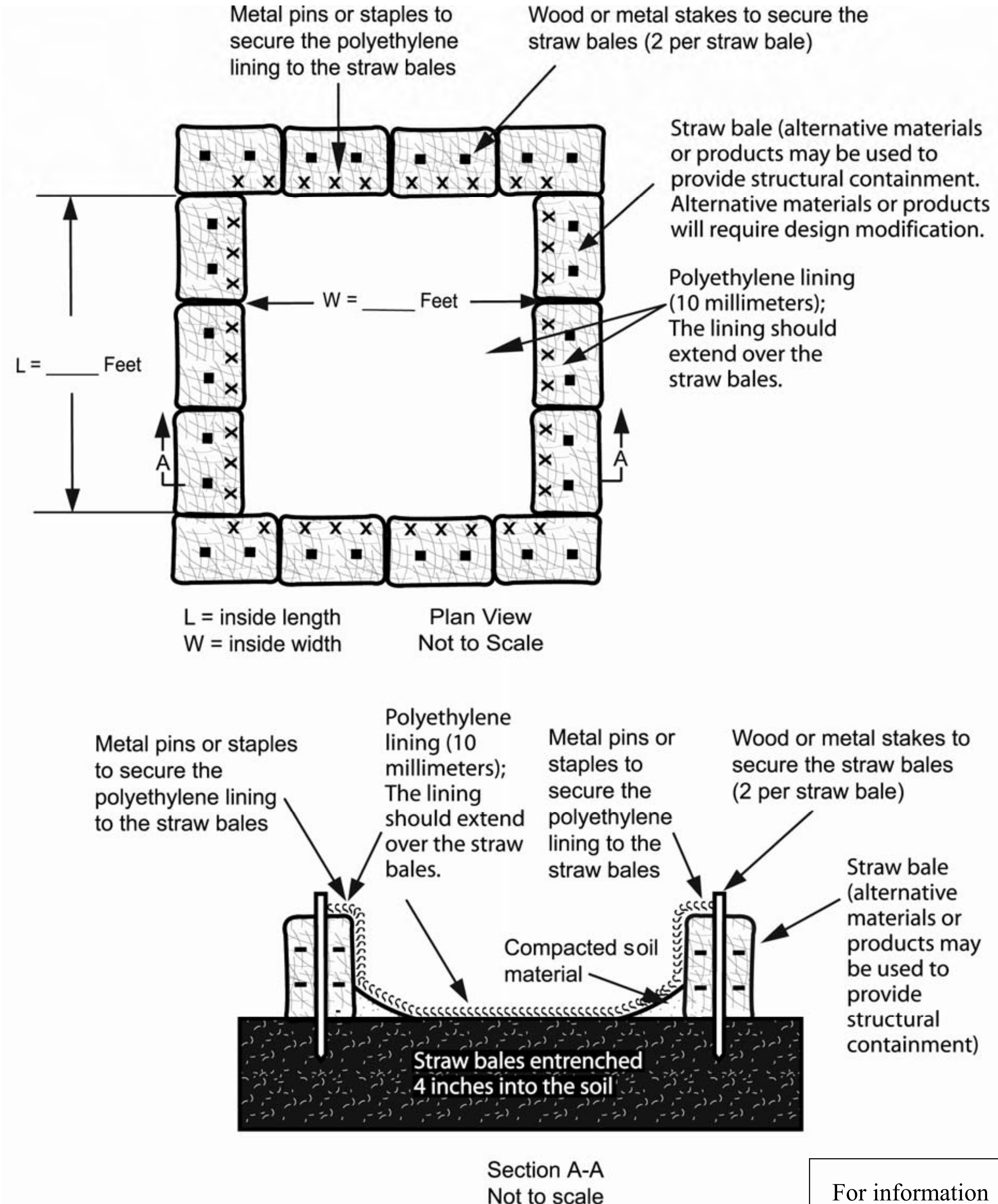
Concrete Washout (Above Grade System) Worksheet



For information on this measure, see Chapter 7, page 247

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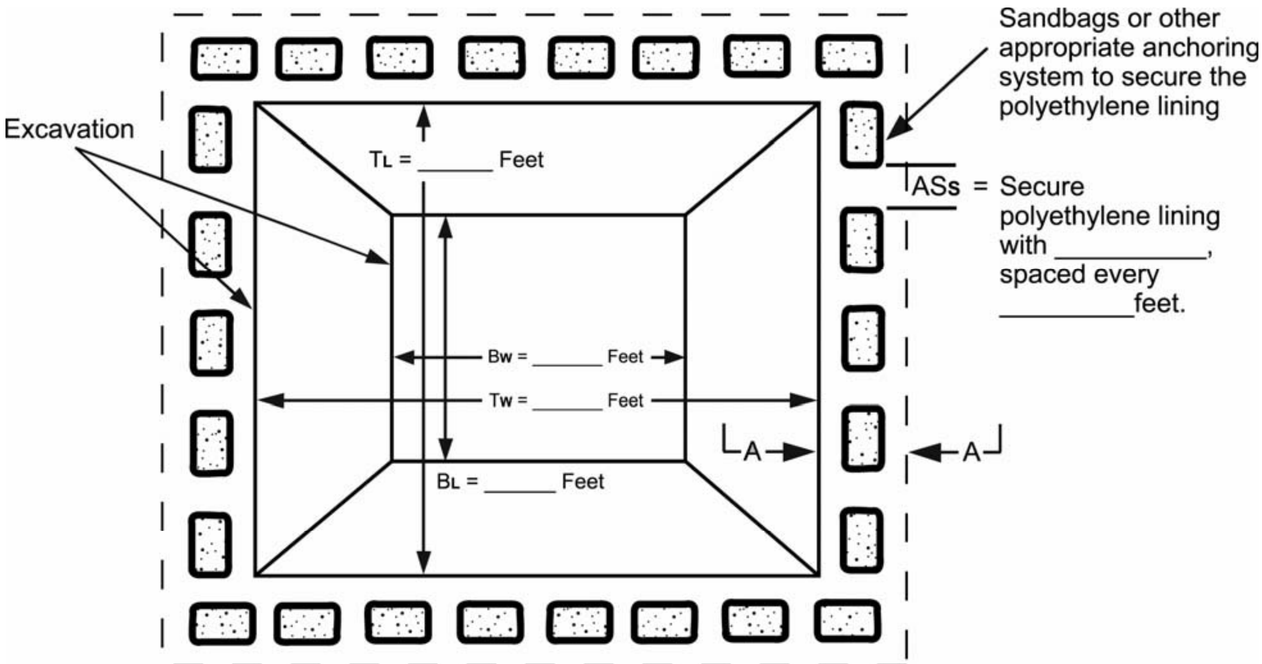
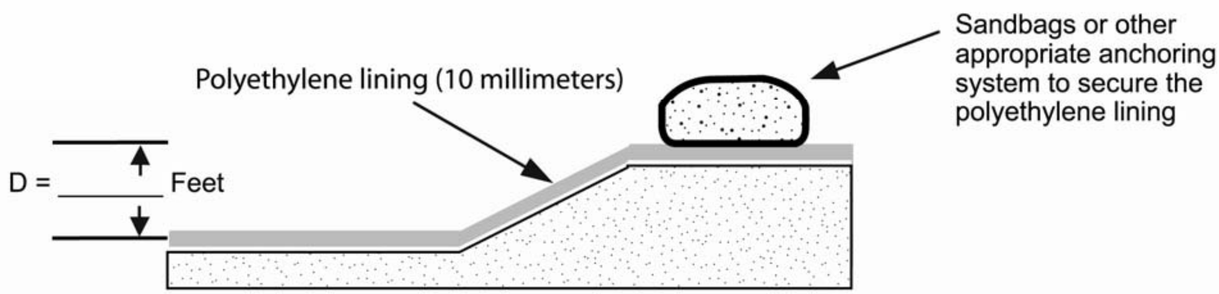
Concrete Washout (Below Grade System) Worksheet



TL = Top Length of Excavation
BL = Bottom Length of Excavation
Tw = Top Width of Excavation
Bw = Bottom Width of Excavation
ASs = Anchoring System type and spacing

Plan View
Not to Scale



Section A-A
Not to Scale

For information on this measure, see Chapter 7, page 247

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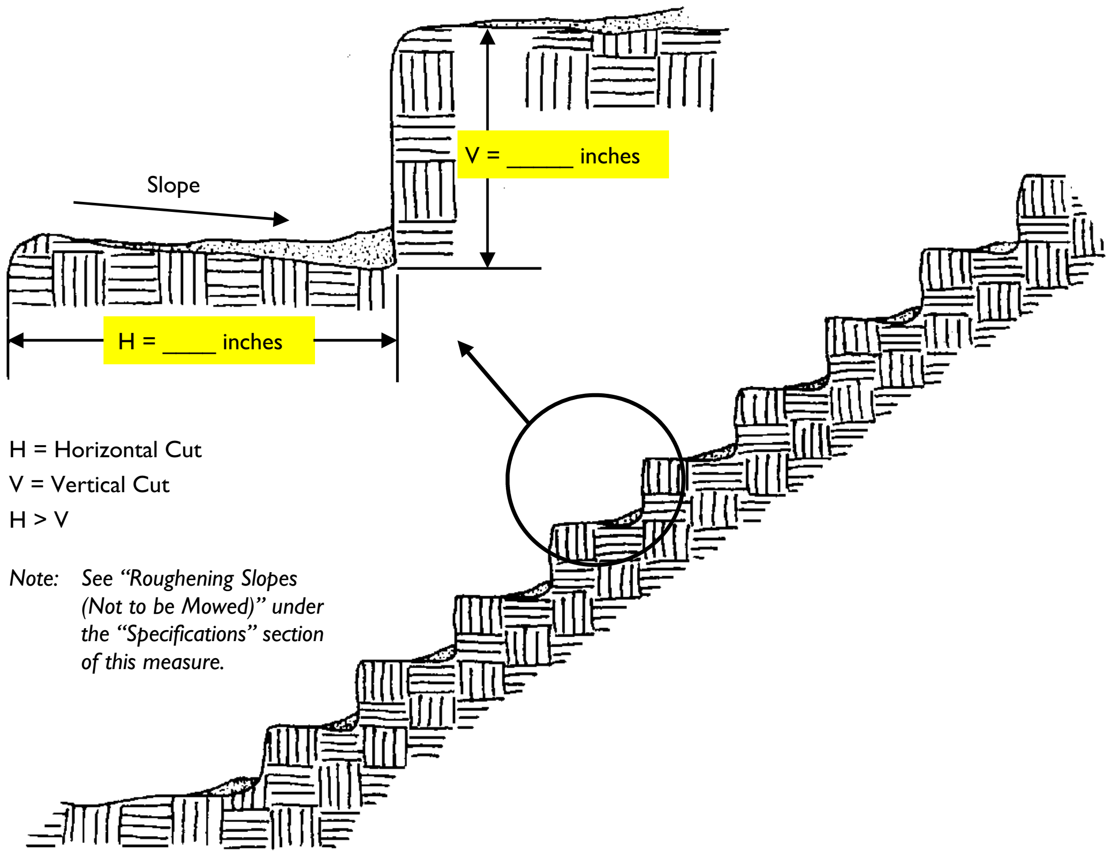
Surface Roughening – Stair-Step Worksheet



Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

For information on this measure, see Chapter 7, page 297

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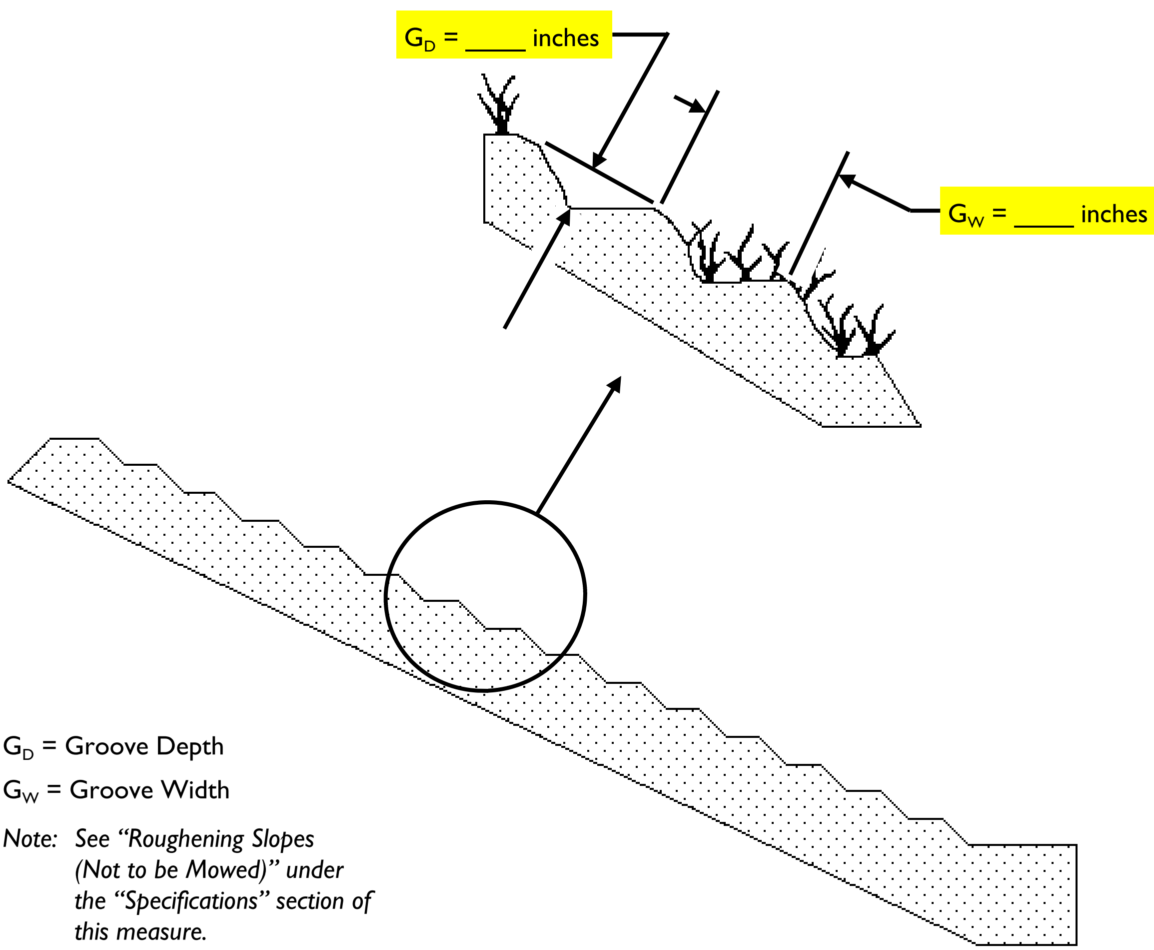
Surface Roughening – Grooving Worksheet



G_D = Groove Depth

G_W = Groove Width

Note: See "Roughening Slopes (Not to be Mowed)" under the "Specifications" section of this measure.

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

For information on this measure, see Chapter 7, page 297

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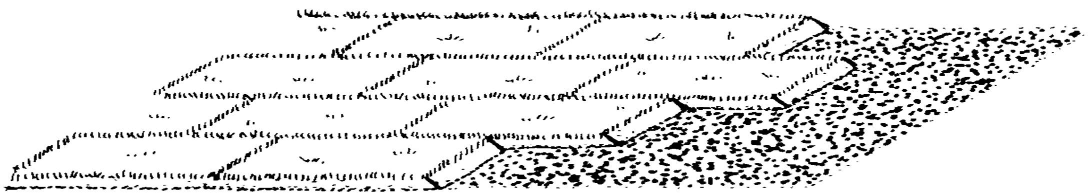
Sod

Exhibit 1

Perspective View



Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

For information on this measure, see Chapter 7, page 47

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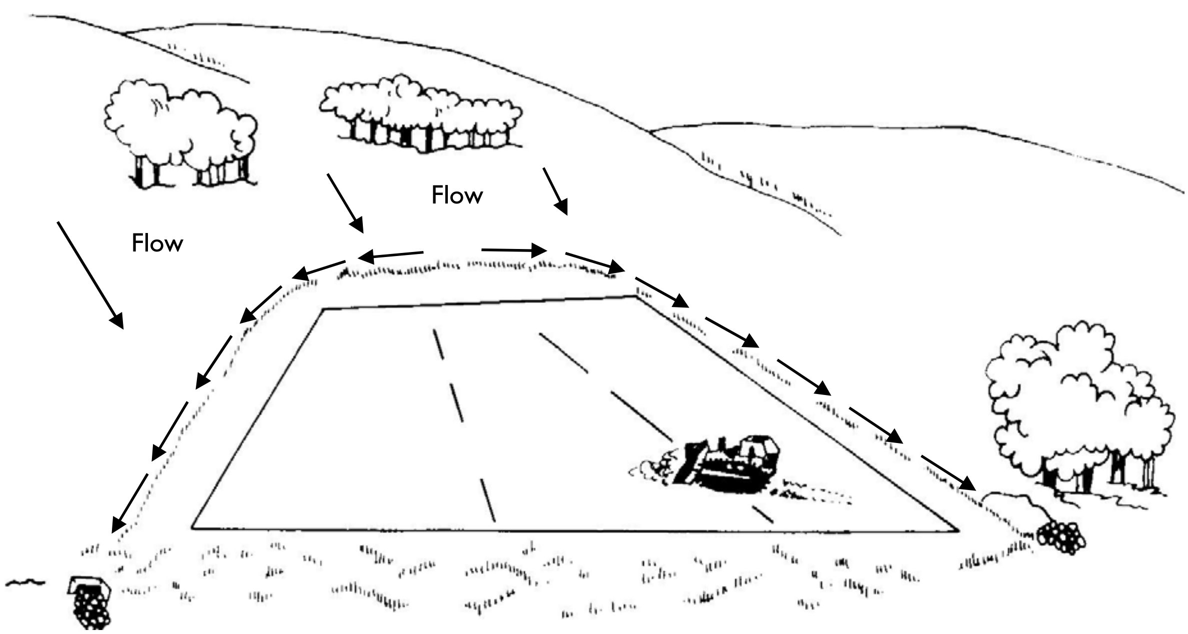
Perimeter Diversion Dike

Exhibit 1

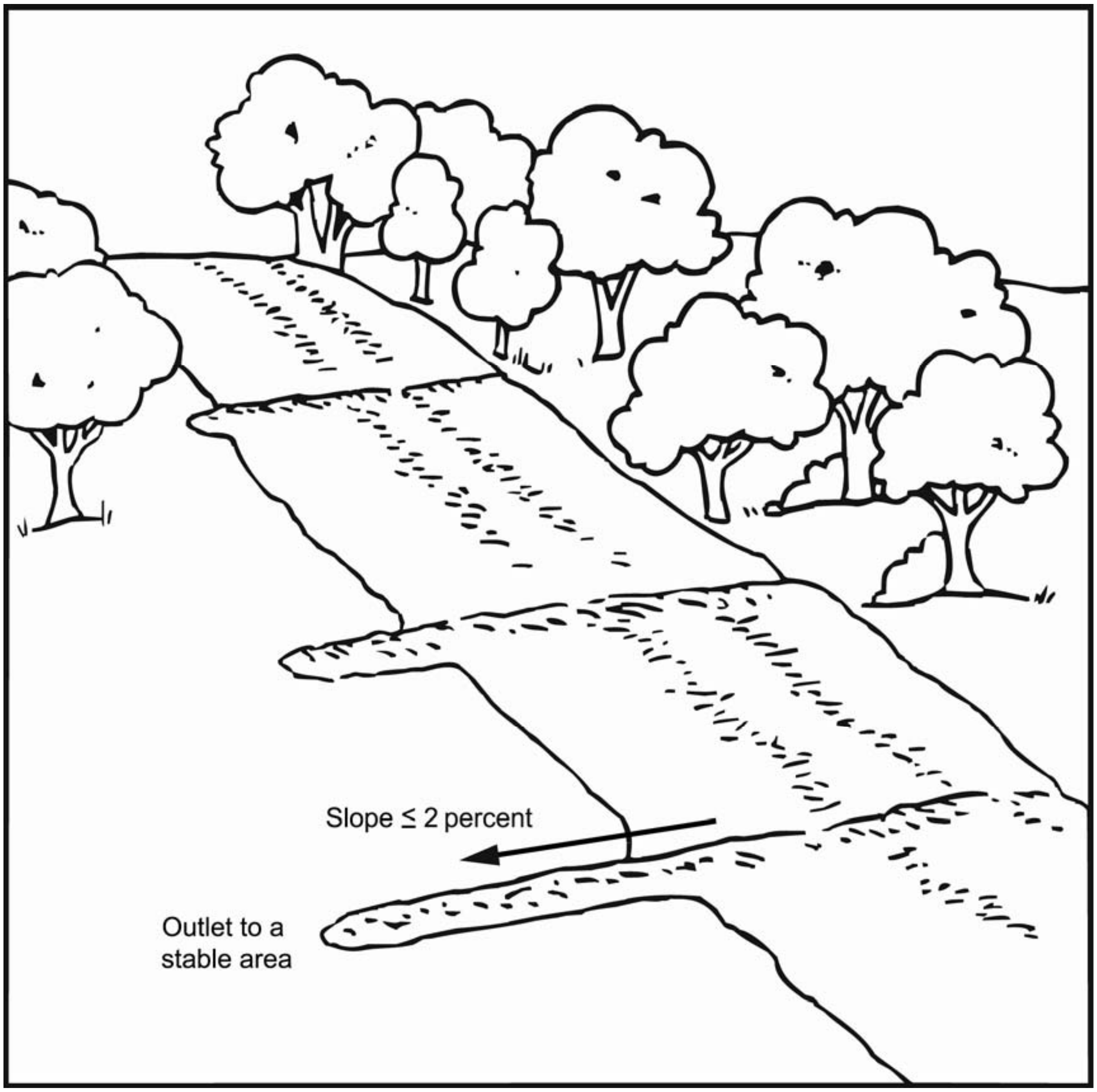


Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

For information on this measure, see Chapter 7, page 83

Water Bar

Exhibit 1



For information on this measure, see Chapter 7, page 89

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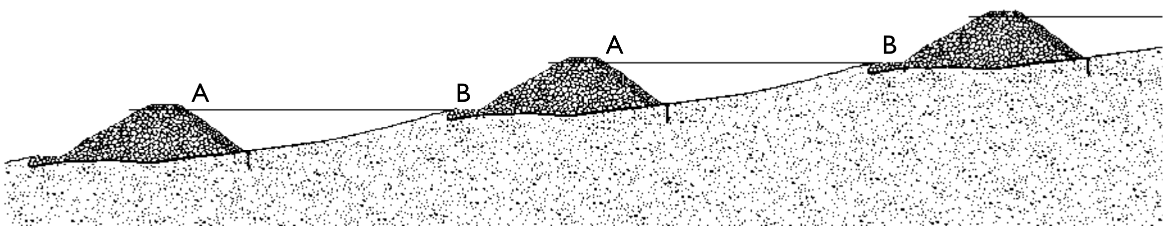
Rock Check Dam

Exhibit 1



A = Crest of Dam

B = Toe of Dam

For information on this measure, see Chapter 7, page 97

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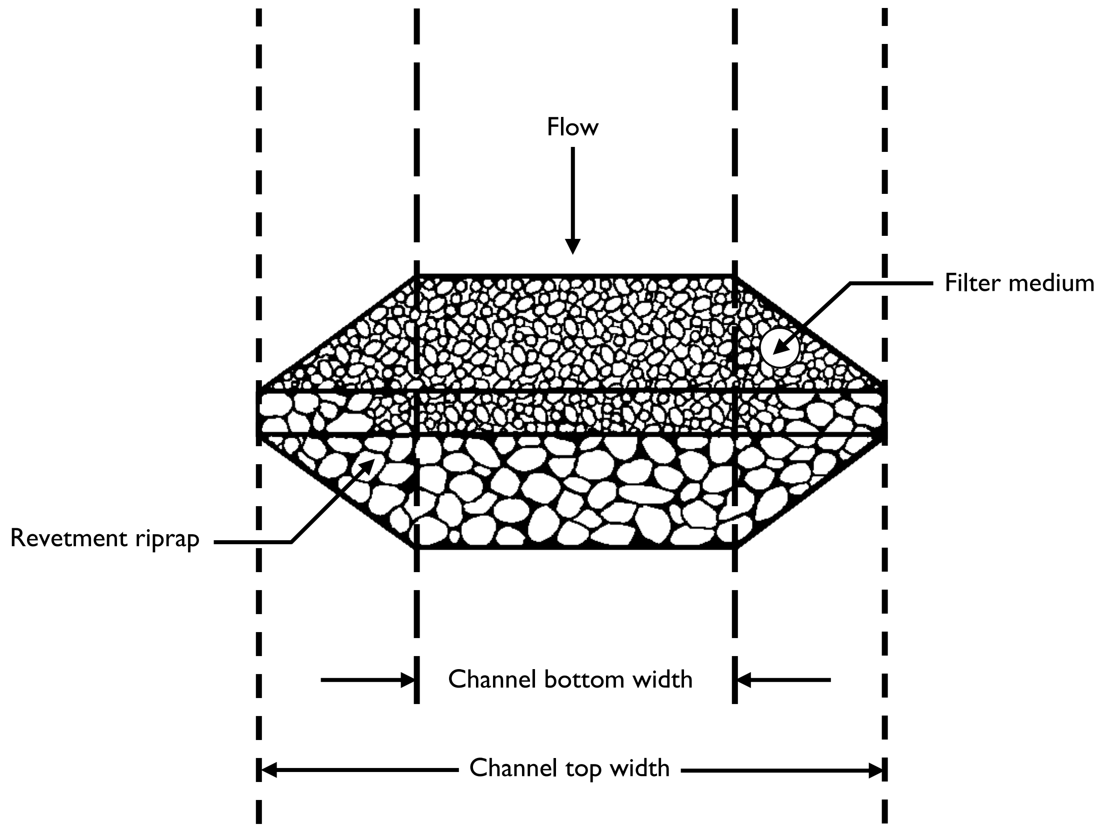
Rock Check Dam

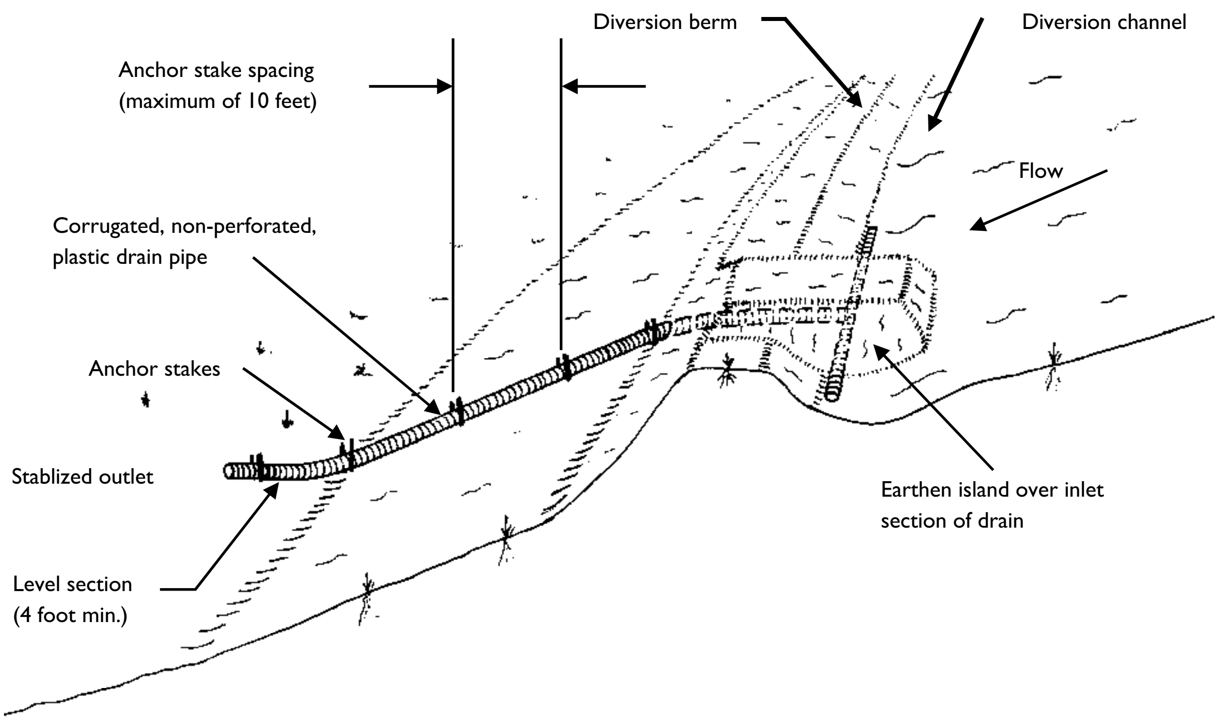
Exhibit 2



For information on this measure, see Chapter 7, page 97

Temporary Slope Drain

Exhibit 1



For information on this measure, see Chapter 7, page 103

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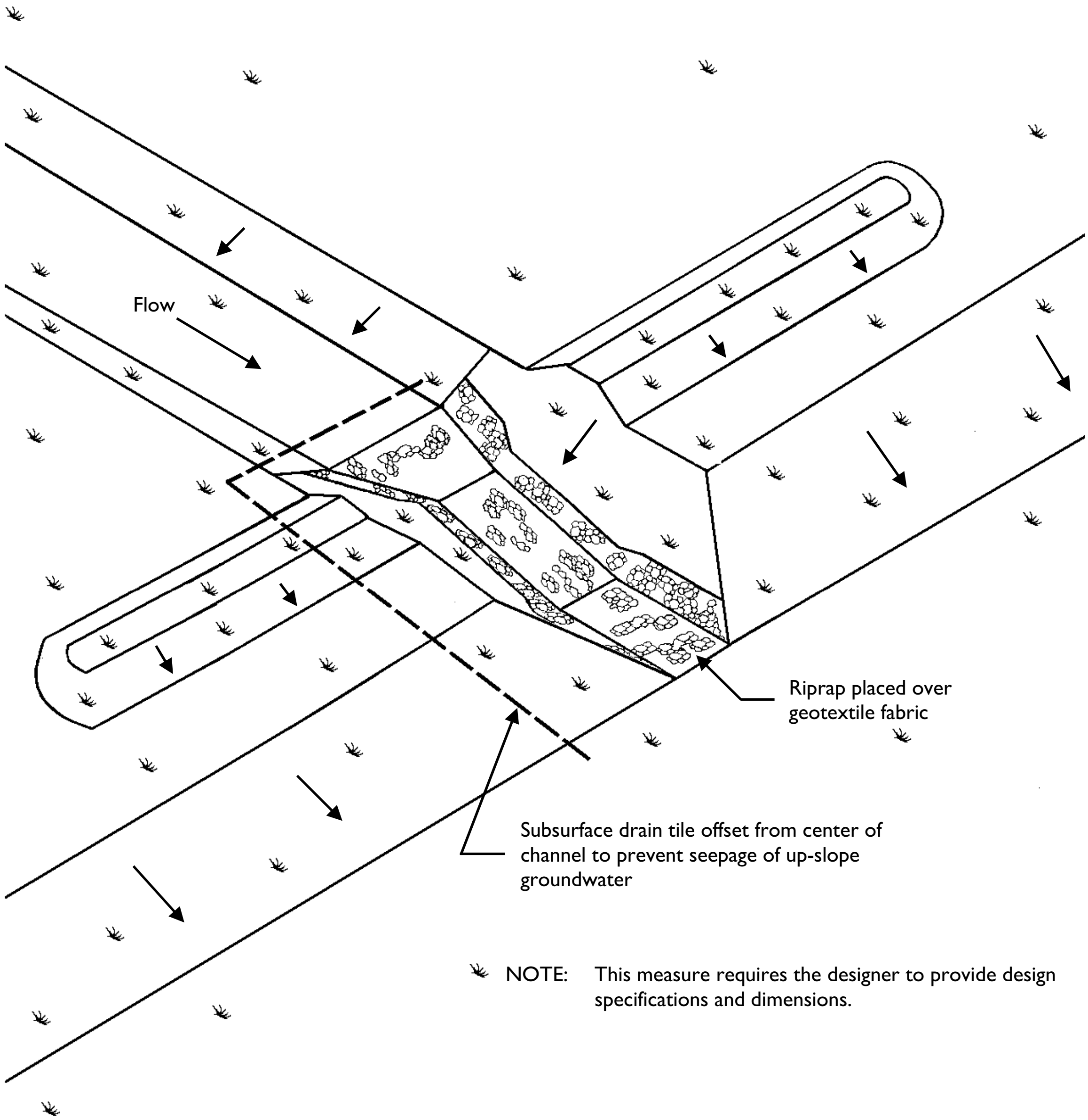
Rock-Lined Chute

Exhibit 1



Source: Adapted from USDA Natural Resources Conservation Service

For information on this measure, see Chapter 7, page 127

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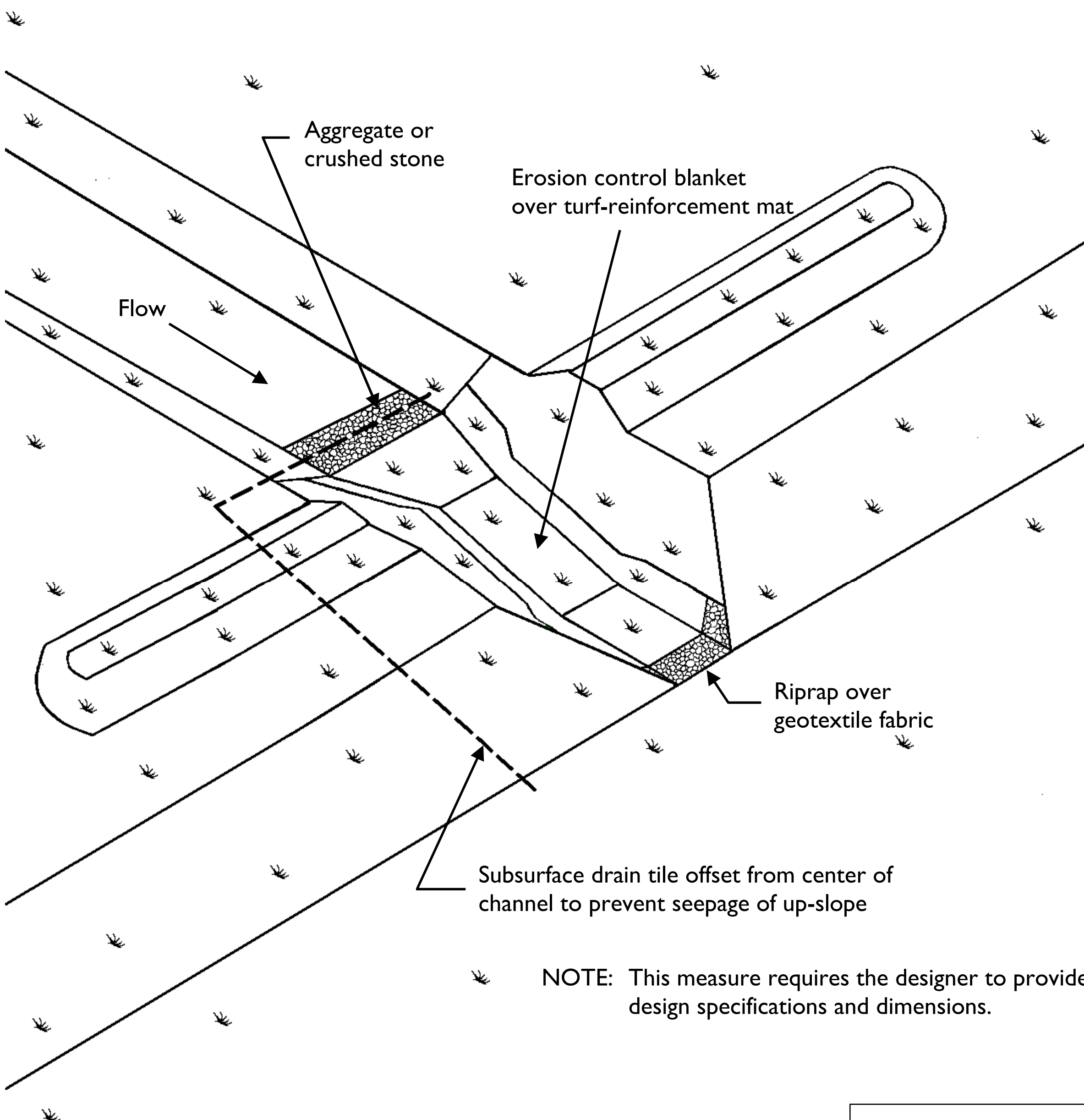
Reinforced Vegetated Chute

Exhibit 1



Source: Adapted from USDA Natural Resources Conservation Service

For information on this measure, see Chapter 7, page 135

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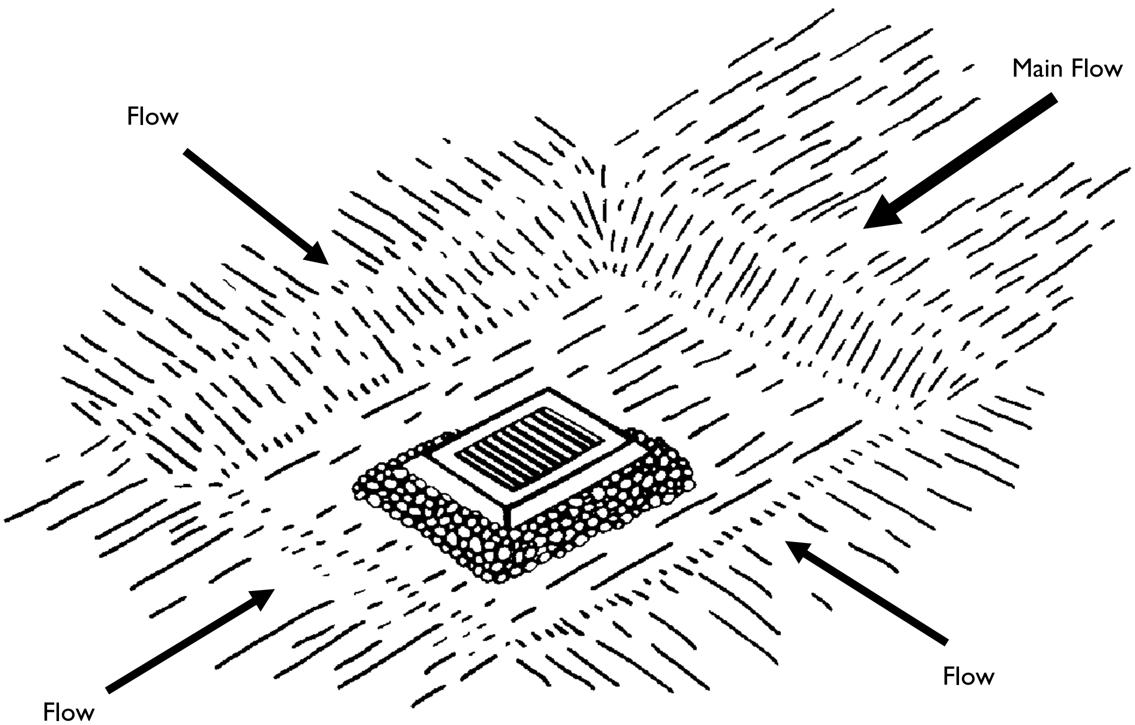
Excavated Drop Inlet Protection

Exhibit 1

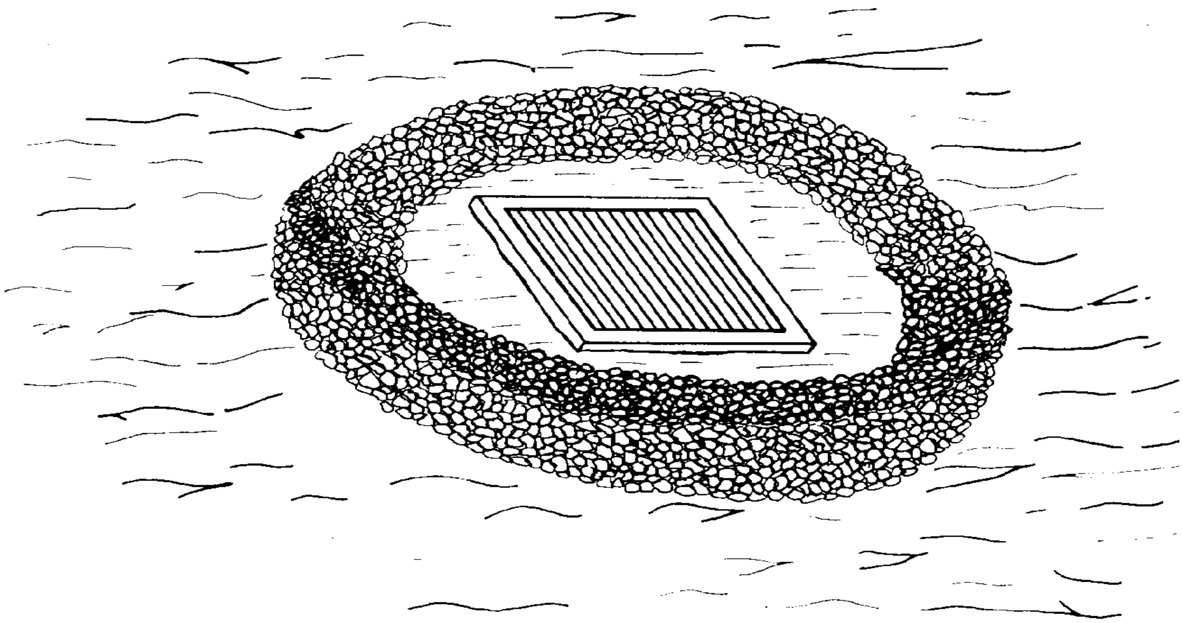


Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

For information on this measure, see Chapter 7, page 145

Gravel Donut Drop Inlet Protection

Exhibit 1



For information on this measure, see Chapter 7, page 149

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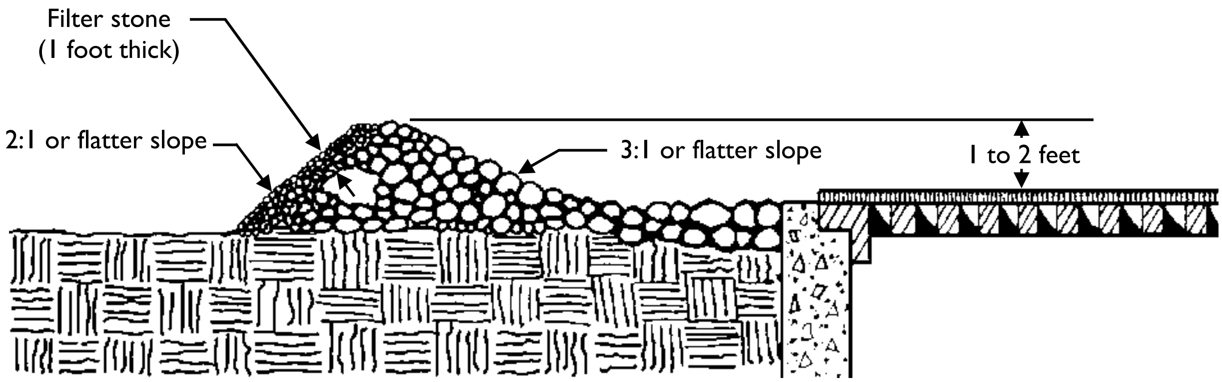
Gravel Donut Drop Inlet Protection

Exhibit 2



Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

For information on this measure, see Chapter 7, page 149

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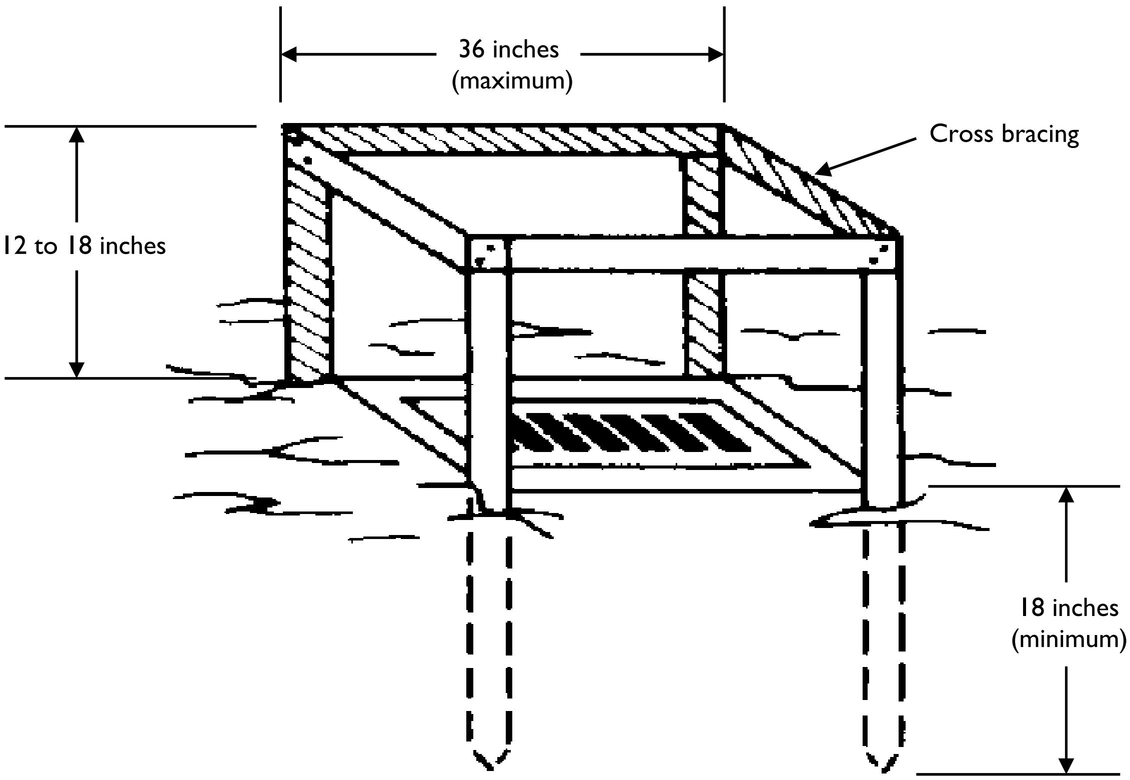
Geotextile Fabric Drop Inlet Protection

Exhibit 1



Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

For information on this measure, see Chapter 7, page 153

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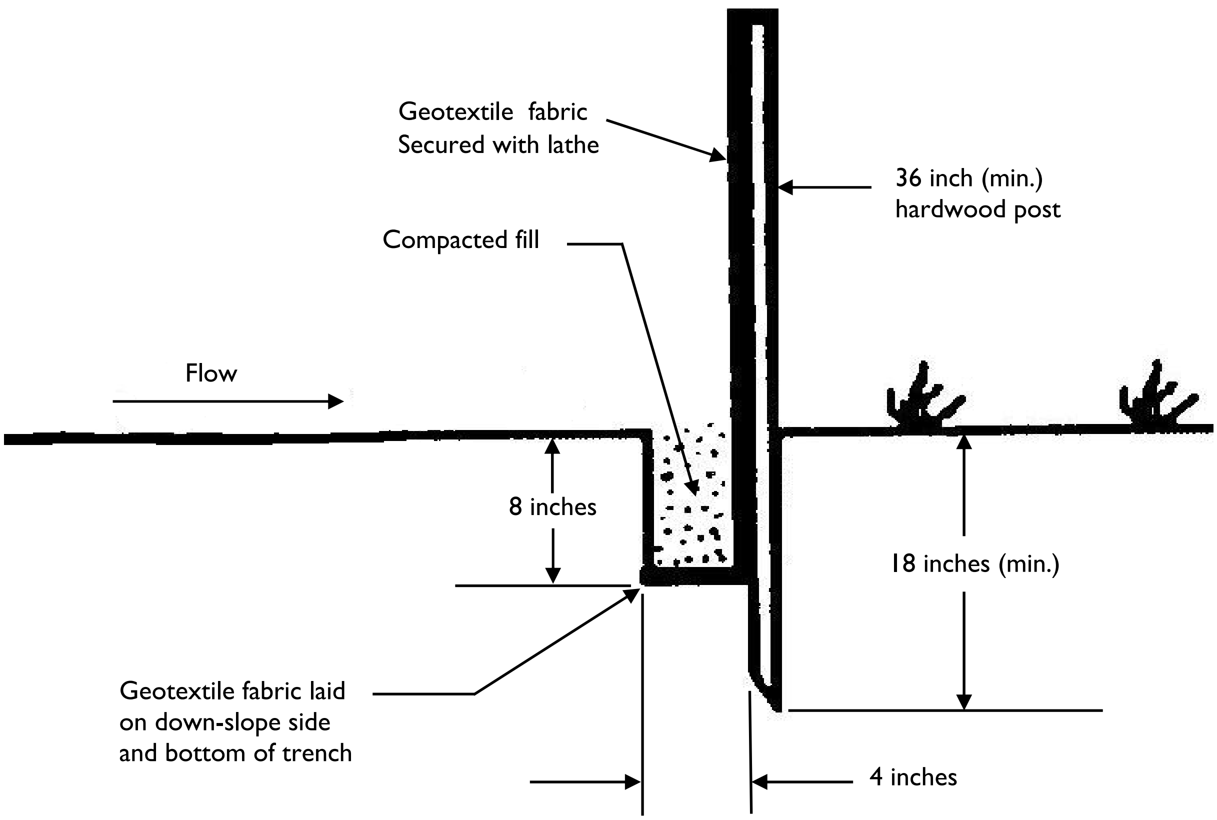
Geotextile Fabric Drop Inlet Protection

Exhibit 2



For information on this measure, see Chapter 7, page 153

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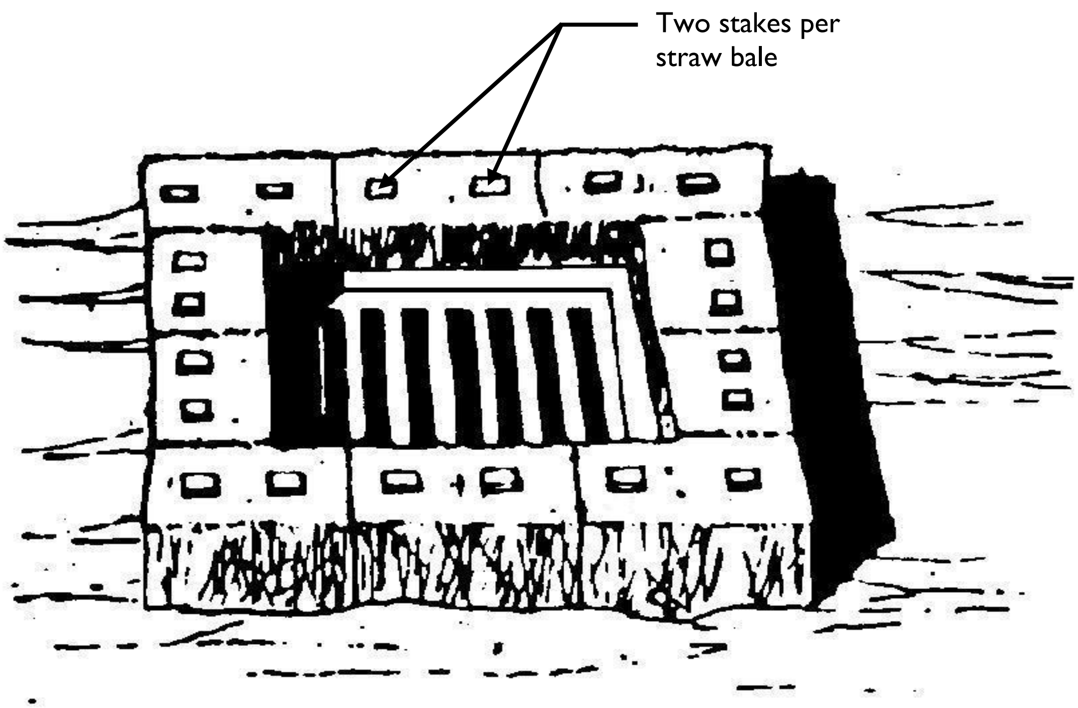
Straw Bale Drop Inlet Protection

Exhibit 1



Source: Adapted from Michigan Soil Erosion and Sedimentation Control Guidebook, 1975

For information on this measure, see Chapter 7, page 159

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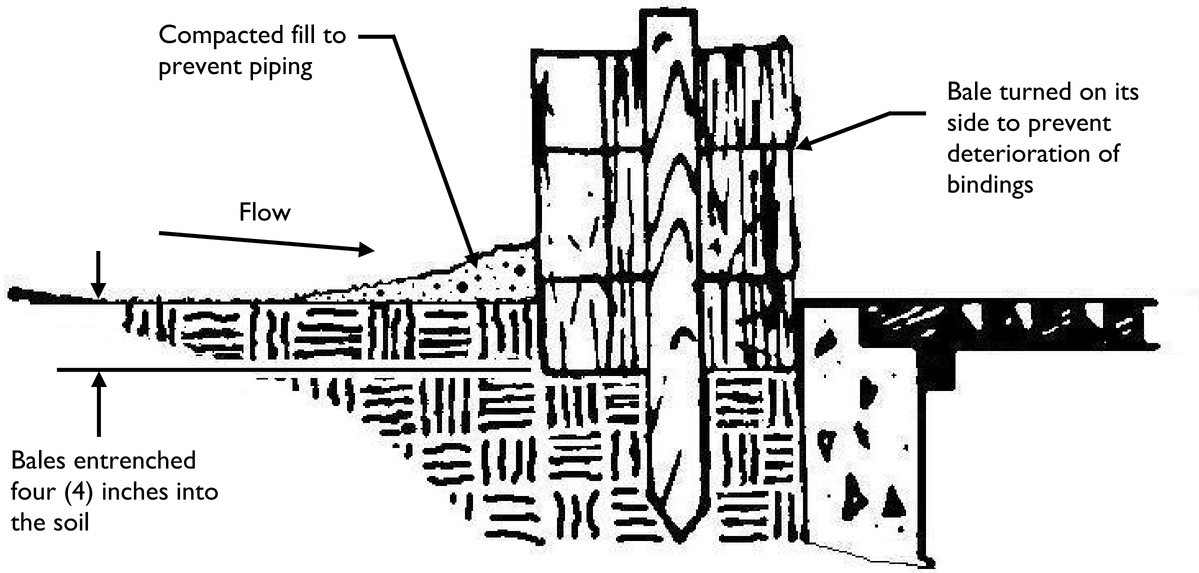
Straw Bale Drop Inlet Protection

Exhibit 2



Source: Adapted from Michigan Soil Erosion and Sedimentation Control Guidebook, 1975

For information on this measure, see Chapter 7, page 159

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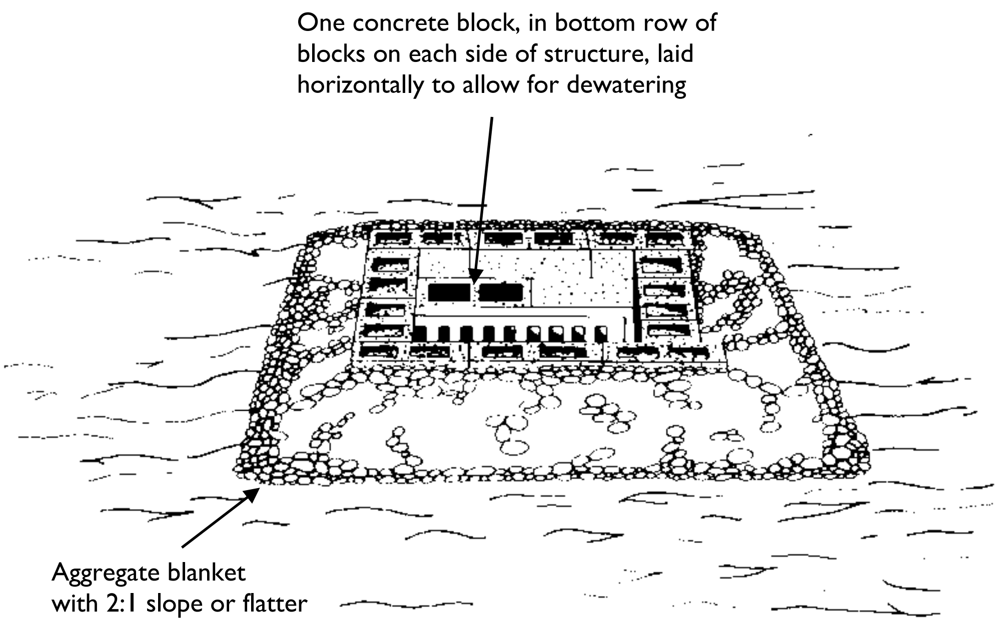
Block & Gravel Drop Inlet Protection

Exhibit 1



Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

For information on this measure, see Chapter 7, page 163

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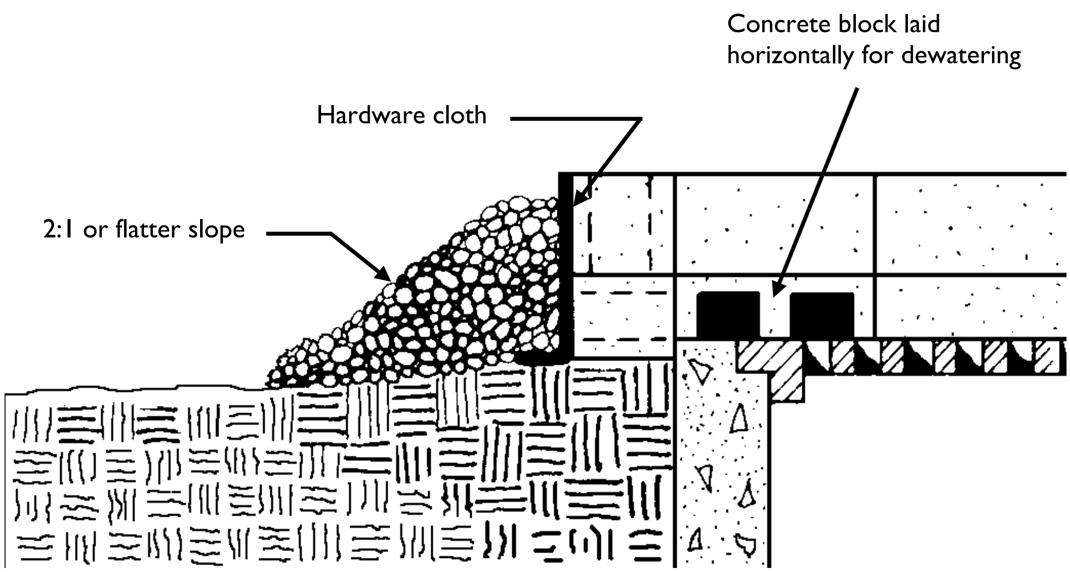
Block & Gravel Drop Inlet Protection

Exhibit 2



Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

For information on this measure, see Chapter 7, page 163

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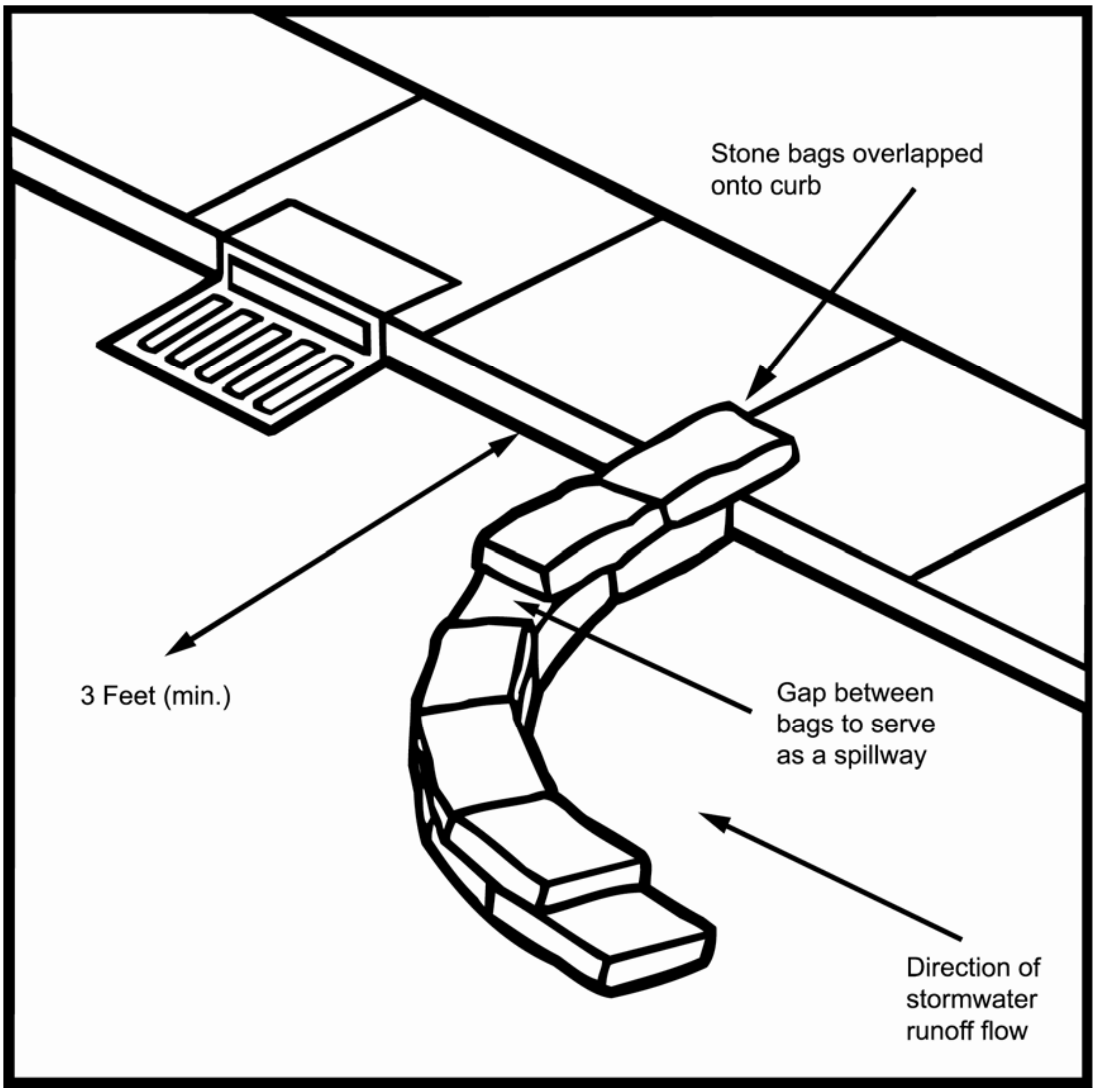
Stone Bag Curb Inlet Protection

Exhibit 1



For information on this measure, see Chapter 7, page 169

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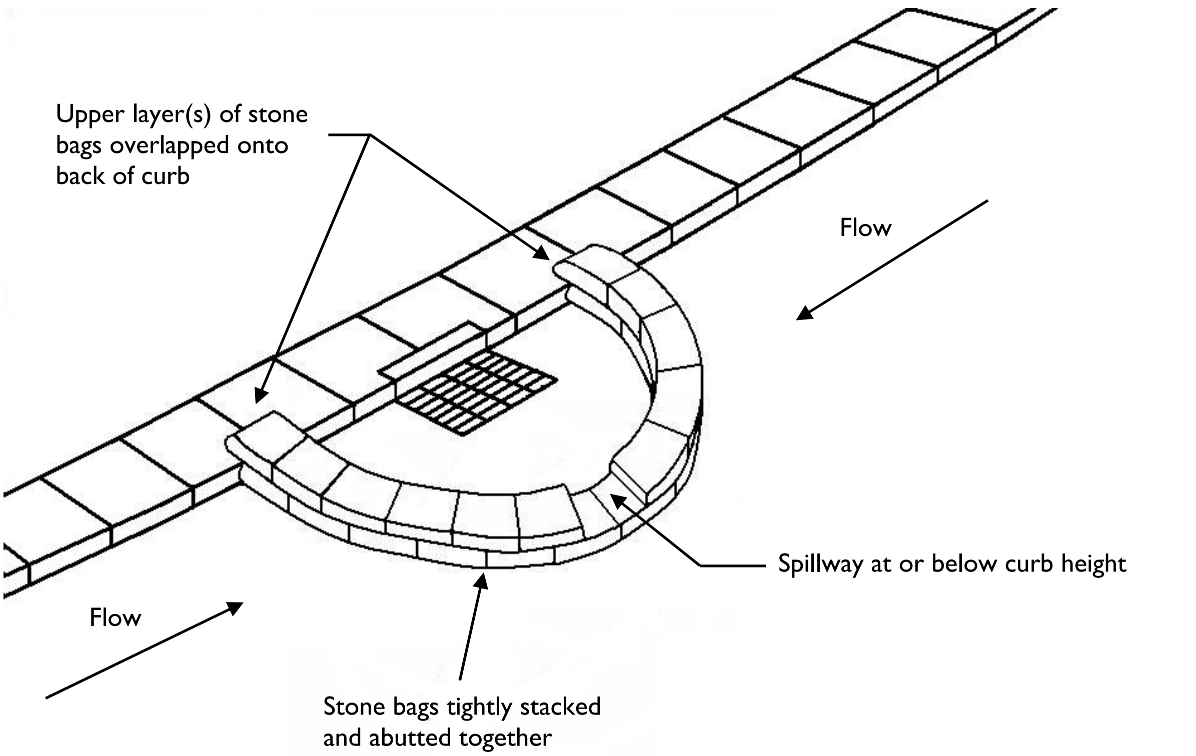
Stone Bag Curb Inlet Protection

Exhibit 2



For information on this measure, see Chapter 7, page 169

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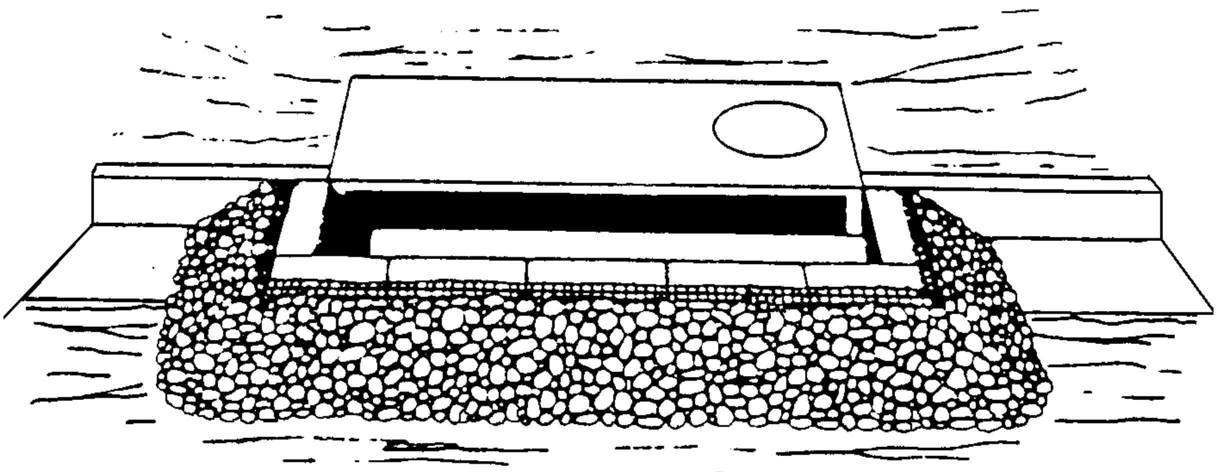
Block & Gravel Curb Inlet Protection

Exhibit 1



Source: Adapted from Virginia Department of Conservation and Recreation, Division of Soil and Water Conservation

For information on this measure, see Chapter 7, page 173

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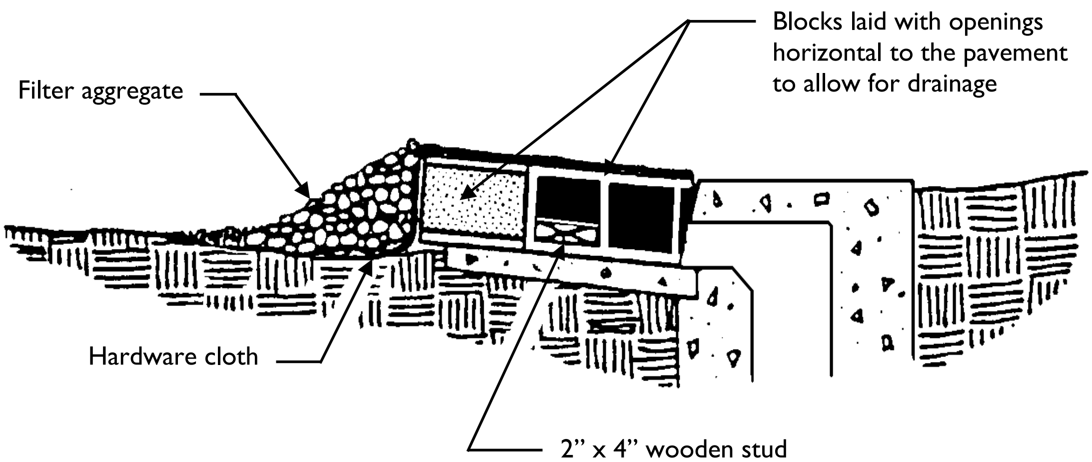
Block & Gravel Curb Inlet Protection

Exhibit 2



For information on this measure, see Chapter 7, page 173

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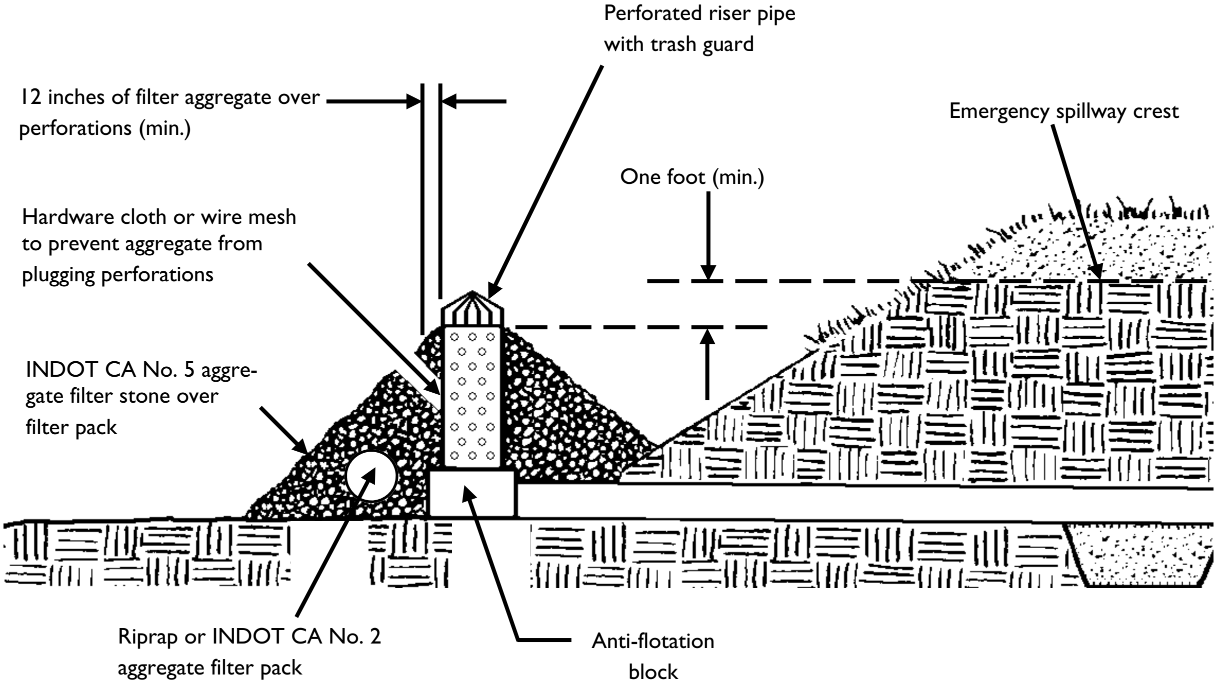
Temporary Dry Sediment Basin Riser Pipe

Exhibit 1



NOTE: For minimum dimensions see the "Specifications" section of this measure.

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual, 1993

For information on this measure, see Chapter 7, page 191

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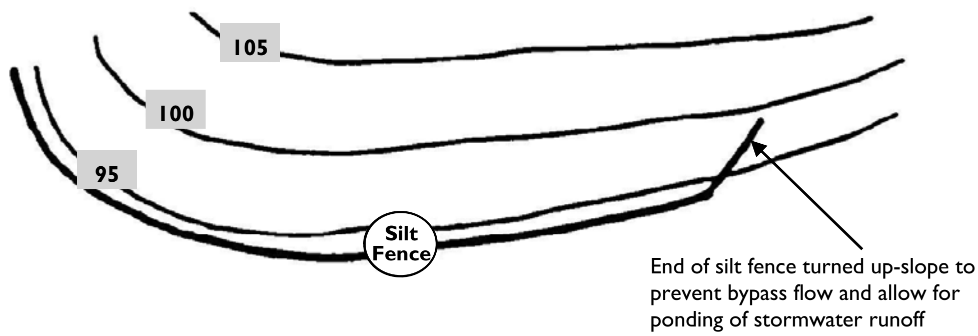
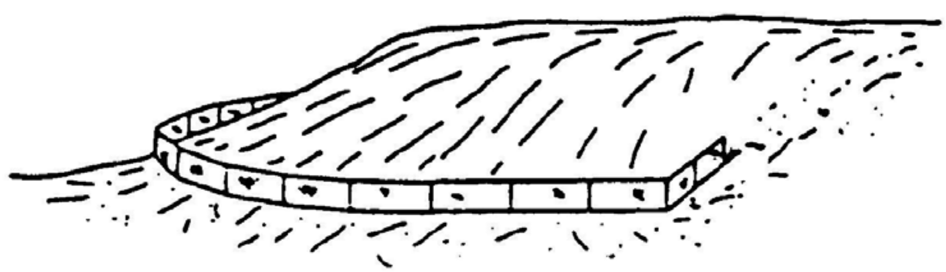
Silt Fence

Exhibit 1





Source: Adapted from Commonwealth of Pennsylvania Erosion and Sediment Pollution Control Program Manual, 1990

For information on this measure, see Chapter 7, page 215

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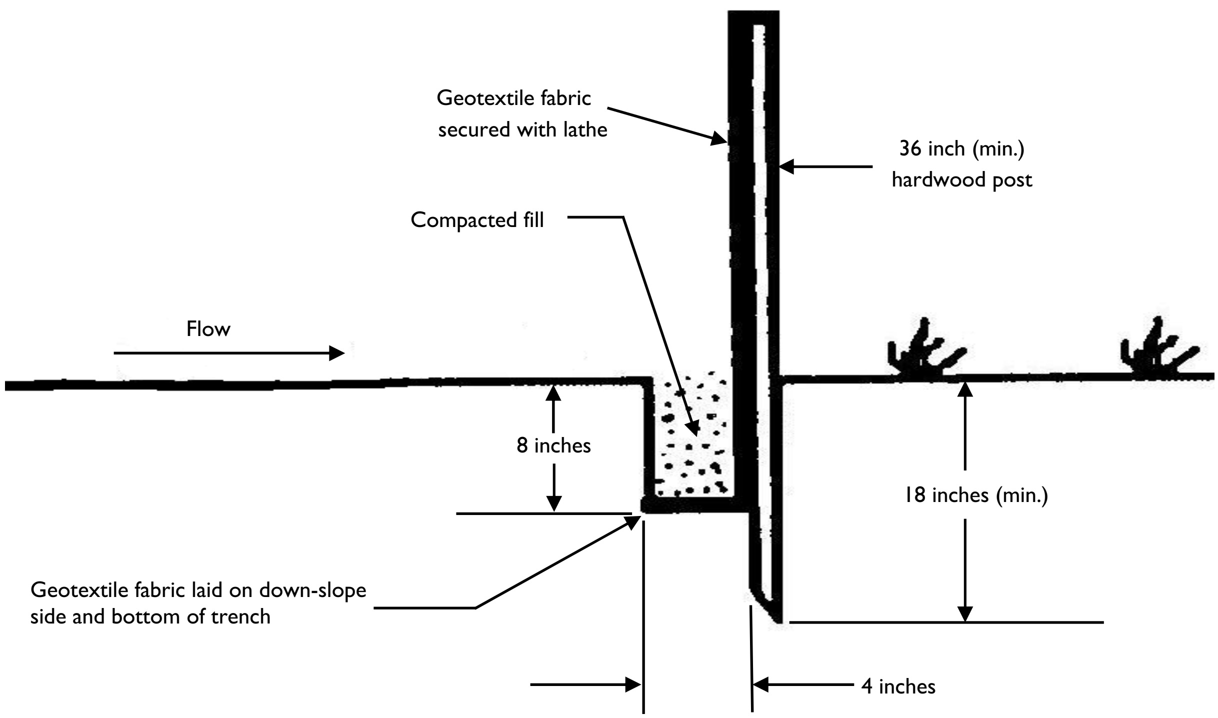
Silt Fence

Exhibit 2



For information on this measure, see Chapter 7, page 215

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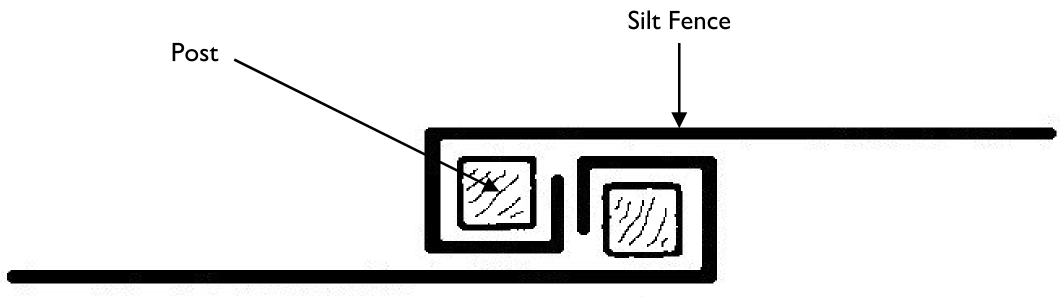
Silt Fence

Exhibit 3



For information on this measure, see Chapter 7, page 215

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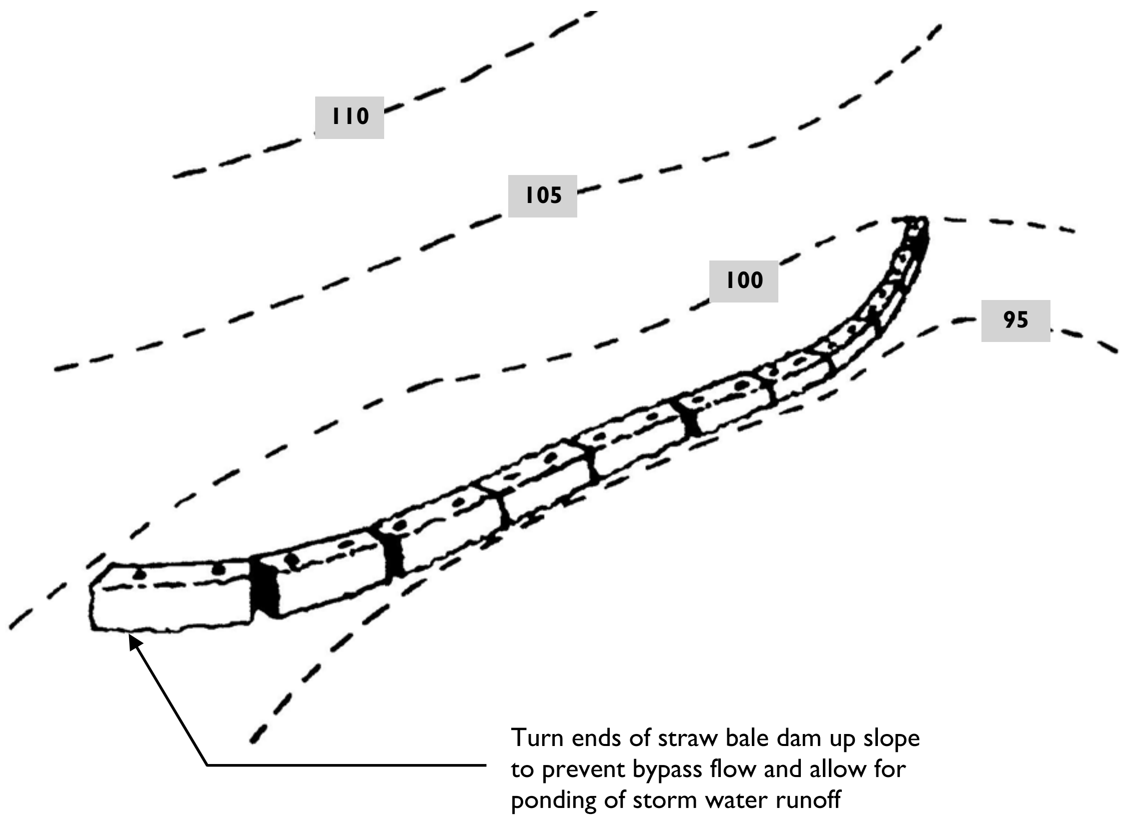
Straw Bale Dam

Exhibit 1



Source: Adapted from Minnesota Pollution Control Agency, Minnesota Construction Site Erosion and Sediment Control Planning Handbook, 1987

For information on this measure, see Chapter 7, page 223

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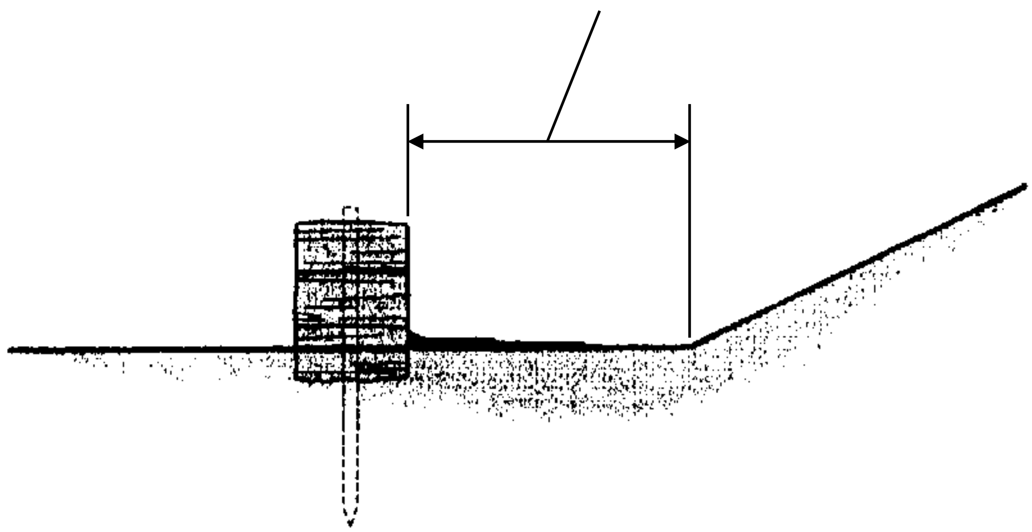
Straw Bale Dam

Exhibit 2



Source: California Regional Water Quality Control Board, San Francisco Bay Region
Erosion and Sediment Control Field Manual, Second Edition

For information on this measure, see Chapter 7, page 223

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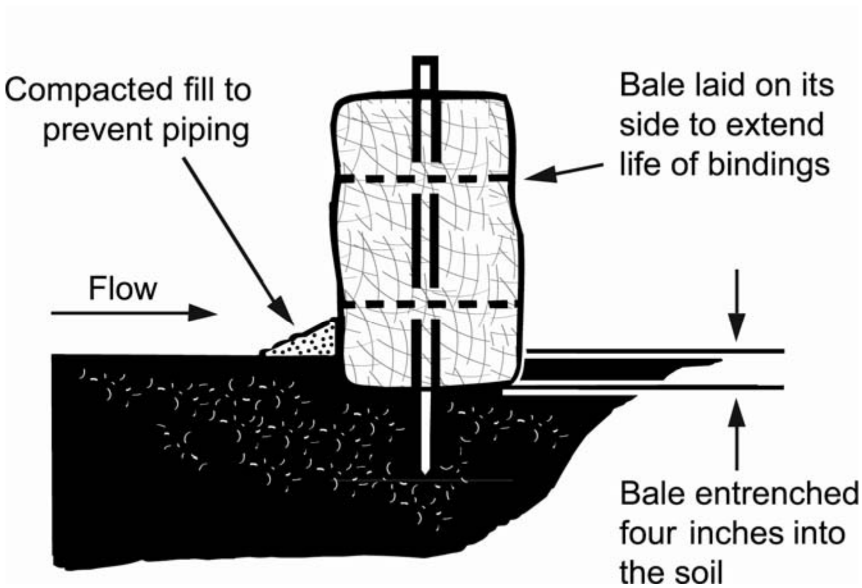
Straw Bale Dam

Exhibit 3



For information on this measure, see Chapter 7, page 223

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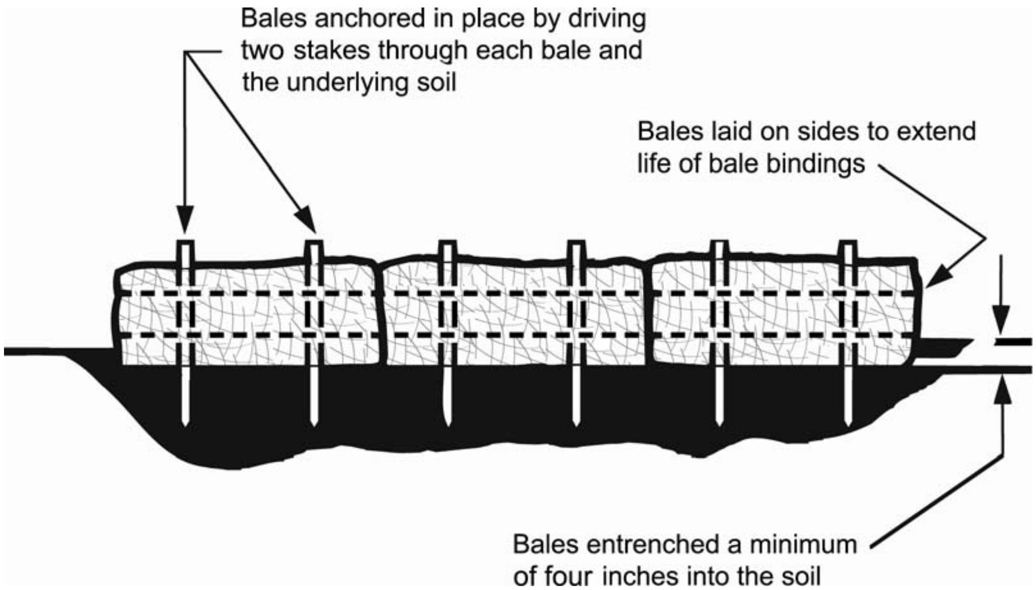
Straw Bale Dam

Exhibit 4



For information on this measure, see Chapter 7, page 223

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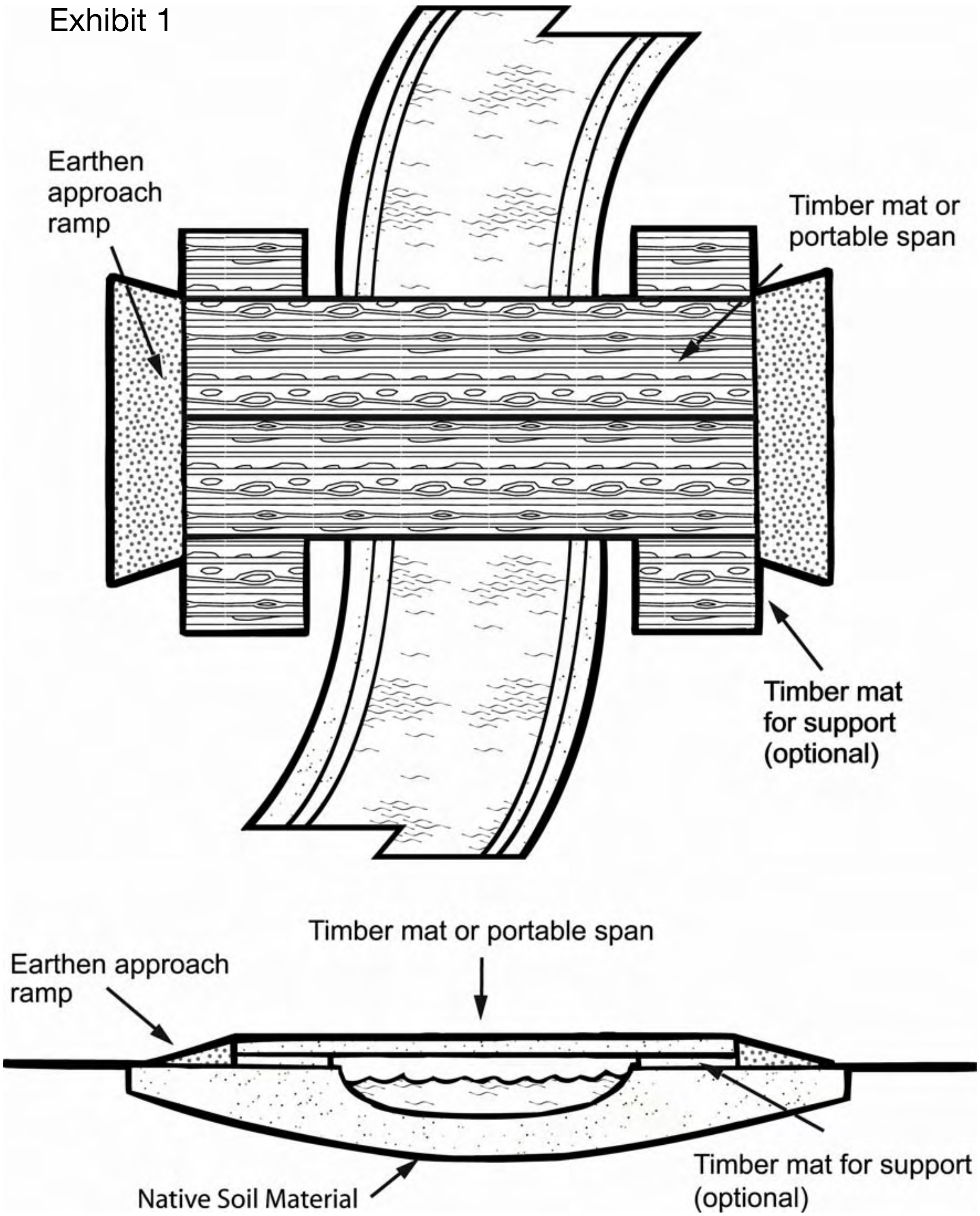
Temporary Stream Crossing - Bridges



NOTE: This measure requires the designer to provide design specifications and dimensions.

For information on this measure, see Chapter 7, page 267

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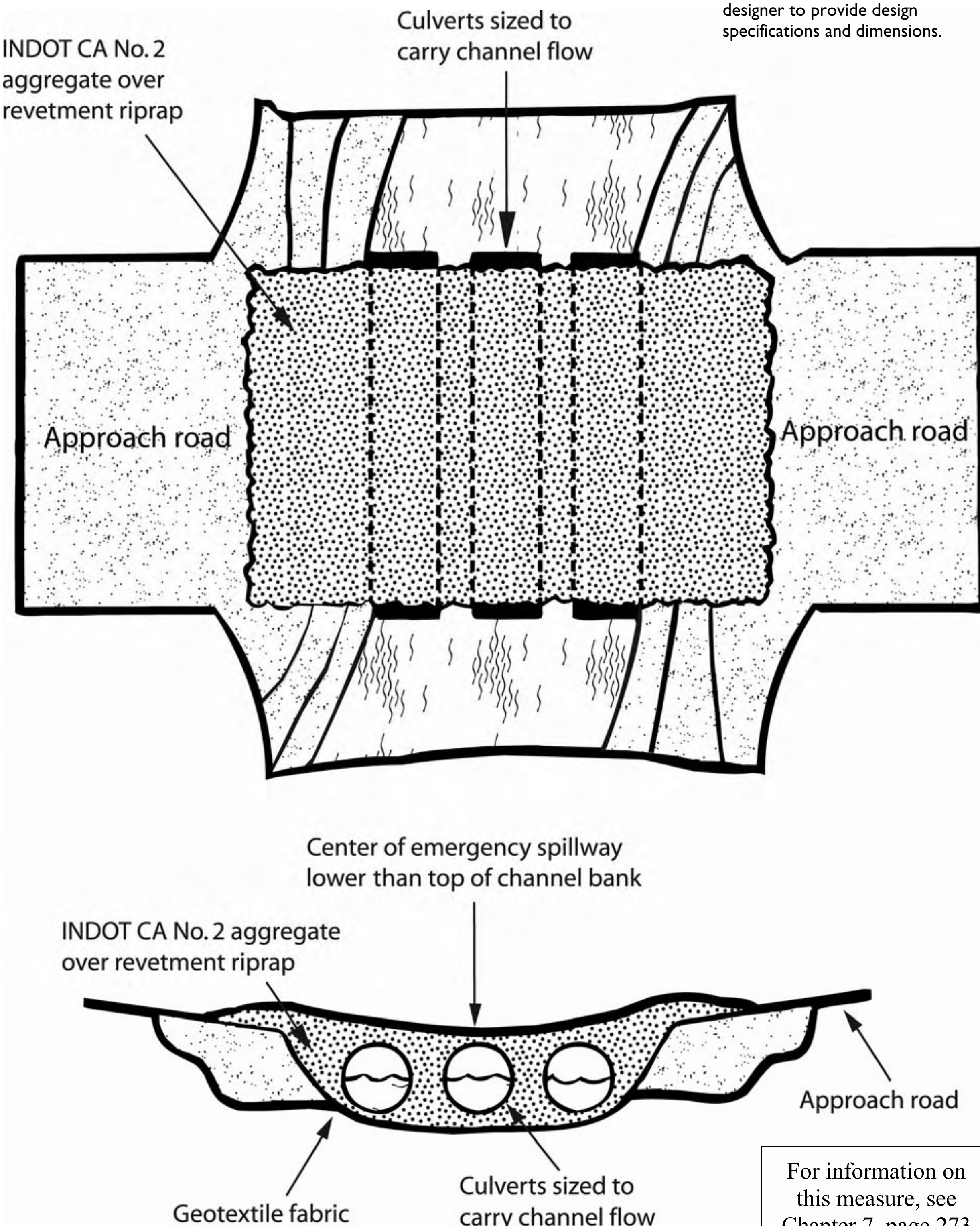
Temporary Stream Crossing - Culverts

Exhibit 1

NOTE: This measure requires the designer to provide design specifications and dimensions.



For information on this measure, see Chapter 7, page 273

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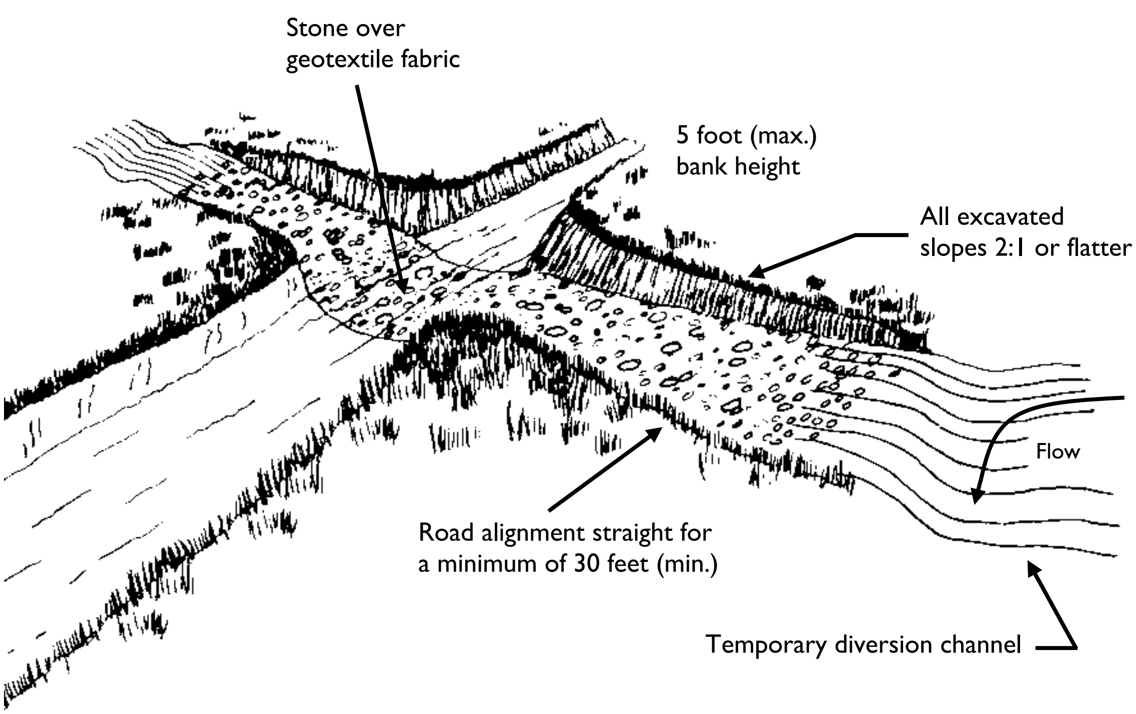
Temporary Stream Crossing - Fords

Exhibit 1



NOTE: This measure requires the designer to provide design specifications and dimensions.

Source: Adapted from Virginia Department of Conservation and Recreation, Division of Soil and Water Conservation, 1992

For information on this measure, see Chapter 7, page 279

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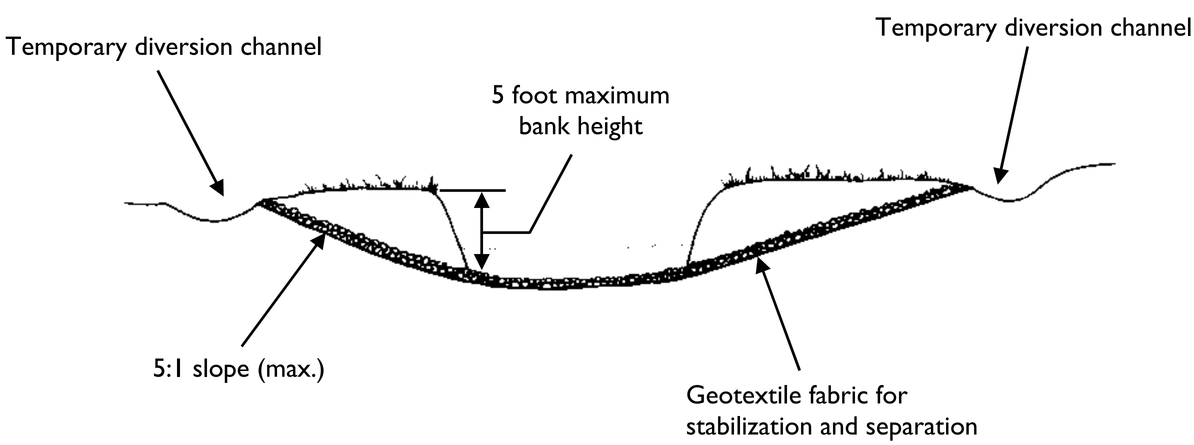
Temporary Stream Crossing - Fords

Exhibit 2



NOTE: This measure requires the designer to provide design specifications and dimensions.

Source: Adapted from Virginia Department of Conservation and Recreation, Division of Soil and Water Conservation, 1992

For information on this measure, see Chapter 7, page 279

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Natural Resources Conservation Service
Construction Specifications

Geotextiles

1. SCOPE

This work shall consist of furnishing all materials, equipment and labor necessary for the installation of geotextiles for slope protection, subsurface drains and road stabilization.

2. MATERIALS

Geotextiles shall be manufactured from synthetic long chain or continuous polymeric filaments or yarns, having a composition of at least 95 percent, by weight, of polypropylene, polyester or polyvinylidene-chloride. The geotextile shall be formed into a stable network of filaments or yarns that retain their relative position to each other, are inert to commonly encountered chemicals and are resistant to ultraviolet light, heat, hydrocarbons, mildew, rodents and insects. The geotextile shall be free of any chemical treatment or coating that might significantly reduce its permeability and shall have no flaws or defects that significantly alter its physical properties. Unless otherwise specified, the class and type of geotextile shall be as shown on the drawings and shall meet the requirements for materials that follow:

a. Woven Geotextile

The woven geotextile shall conform to the physical properties listed in Table 1. The woven geotextile shall be manufactured from monofilament yarns that are woven into a uniform pattern with distinct and measurable openings. The geotextile shall be manufactured so that the yarns will retain their relative position with regard to each other. The yarns shall contain stabilizers and/or inhibitors to enhance their resistance to ultraviolet light or heat exposure. The edges of the material shall be selvedged or otherwise finished to prevent the outer yarn from unraveling.

b. Nonwoven Geotextile

Nonwoven geotextiles shall conform to the physical properties listed in Table 2. Nonwoven geotextiles shall be manufactured from randomly oriented fibers that have been mechanically bonded together by the needle-punched process. Nonwoven geotextiles, in addition to mechanically bonded, nonwoven geotextiles, may be used for Road Stabilization. The filaments shall contain stabilizers and/or inhibitors to enhance their resistance to ultraviolet light or heat exposure.

c. Shipping, Product Identification, Certification and Test Data

The geotextile shall be shipped in rolls wrapped with a protective covering to keep out mud, dirt, dust, debris and direct sunlight. Each roll of geotextile shall be clearly marked to identify the brand, type and production run.

The geotextile shall meet the specified requirements (Table 1 or 2) for the product style or type shown on the label. The manufacturer or distributor will provide a letter of certification to the NRCS Engineer or the designated representative stating the compliance of the delivered product to the requirements of Table 1 or Table 2, whichever is applicable. Test data pertaining to the production run of the product must be submitted to the Engineer if requested to do so, in writing, by the Engineer.

All geotextile materials will be subject to sampling and testing by an independent testing laboratory at any time until final inspection and acceptance.

3. STORAGE

Prior to use, the geotextile shall be stored in a clean, dry place, out of direct sunlight, not subject to extremes of either hot or cold, and with the manufacturer's protective cover in place.

4. SURFACE PREPARATION

The surface on which the geotextile is to be placed shall be graded to the neat lines and grades as shown on the drawings. The surface shall be reasonably smooth and free of holes, sharp objects and projections. The surface preparation will be inspected and approved by the NRCS Engineer or the designated representative prior to placing the geotextile.

5. PLACEMENT

a. General

The geotextile shall be placed on the approved, prepared surface at the locations and in accordance with the details shown on the drawings. The geotextile shall be unrolled along the placement area and loosely laid (not stretched) in such a manner that it will conform to the surface irregularities when stone or other material is placed on or against it. No cuts or punctures will be permitted in the geotextile. The geotextile may be folded and overlapped to permit proper placement in the designated area.

Where seaming is required or desired, the seam shall be composed of a sewing thread having a composition of at least 95 percent polypropylene, polyester or polyarimid. The sewing thread shall have a minimum breaking strength of 28 pounds when tested in accordance to ASTM D 2256-80 and shall be highly contrasting in color to the geotextile. The seam shall conform to Federal Standard SSa-2, SSn-2 or SSd-2, using a minimum of 4 stitches per inch per stitch line. The stitch lines shall be parallel, a maximum of 0.75 inches apart and parallel to the geotextile edge (SSa) or fold (SSn or SSd). The stitch line closest to the edge or fold shall be no more than 2 inches and no less than 0.75 inches from the edge or fold. Federal Standard 401 or 301 stitches shall be used. Federal Standard 101 stitches will not be accepted.

b. Slope Protection

The roll or panel length shall be placed parallel to the direction of water flow unless otherwise indicated on the drawings. The geotextile's terminal end details shall be as shown on the drawings. The minimum overlap shall be 18 inches, in any direction, unless adjacent panels are sewn together.

The geotextile shall not be placed until it can be anchored and protected with the intended covering within 48 hours. If the geotextile will not be covered within 48 hours, a temporary covering will be used for protection from ultraviolet light.

Securing pins, approved by the NRCS Engineer or the designated representative and provided by the geotextile manufacturer, shall be placed along the edge of the panel to adequately secure it during placement, except as noted under item d. below. At vertical laps, securing pins shall be inserted through both layers along a line through the approximate midpoint of the overlap. At horizontal laps and laps across slopes, securing pins shall be inserted through the bottom layer only. Securing pins shall be placed along a line approximately 2 inches in from the edge of the outer limits of the placed geotextile at intervals not greater than 12 feet, unless otherwise specified. Additional pins shall be installed as necessary to prevent any slippage of the fabric, regardless of locations. The use of securing pins will be held to the minimum necessary. The fabric may be secured with other methods when specified or directed by the NRCS Engineer or the designated representative. Pins shall be steel or fiberglass, formed as a "U", "L", or "T" shape or with "ears" to prevent total penetration. Steel washers shall be provided on all but the "U"-shaped pins.

c. Subsurface Drains

The geotextile shall be covered by drainfill or other material within the same working day. Drainfill material shall be placed in a manner that prevents damage to the geotextile. In no case will material be dropped on uncovered fabric from a height greater than 5 feet. The minimum overlap of adjacent geotextile panels for unsewn fabric shall be as follows:

1) Trench drain - 12 inches
2) Blanket drain - 18 inches

d. Road Stabilization

The geotextile shall be unrolled parallel to the roadway centerline. The minimum overlap of adjacent geotextile panels shall be 24 inches for unsewn fabric. Alternately, adjacent panels may be sewn together per item 5a. above.

Securing pins, approved by the NRCS Engineer or the designated representative and provided by the geotextile manufacturer, may be used when necessary to ensure temporary anchoring of the geotextile during the installation process. The pins shall be removed prior to permanent backfilling.

Backfill will be dumped and spread in a uniform thickness generally not to exceed 9 inches after compaction. The first 2 or 3 lifts may be used to seal and consolidate with only light compaction. Over-stressing the soil and severe rutting should be avoided by utilizing spreading and dumping equipment that exerts only moderate pressures on the soil. Granular backfill depths may have to be increased and equipment loads reduced to control soil stress if determined necessary by the NRCS Engineer or the designated representative. Ruts developed during spreading and compacting will be filled with additional backfill material so that backfill thickness can be maintained. In no case will blading or backblading of a rutted surface be allowed to reduce rut depth.

Gravel and other coarse-grained backfill will be compacted with vibratory rollers. Vibration will not be used for coarse-grained backfill when the resulting dynamic forces will cause a loss in subgrade or backfill soil strength; e.g., fine sand backfill over a sand or silt subgrade having a high water table. If such conditions exist, moderate to heavy static rollers (steel drum or rubber tired) will be used. Fine-grained backfill will be compacted with sheepsfoot or rubber tired rollers.

6. ADDITIONAL ITEMS WHICH APPLY TO THIS JOB

TABLE 1 - REQUIREMENTS FOR WOVEN GEOTEXTILES BY USE

Property	Test Method	Slope Protection Unprotected Class I and Protected Class II	Road Stabilization Class IV
Tensile Strength - lbs. 1/	ASTM D 4632	200 min.	180 min.
Bursting - Strength psi 1/	ASTM D 3786	400 min.	NA.
Elongation - % 1/	ASTM D 4632	<50	<50
Puncture - lbs. 1/	ASTM D 4833	90 min.	60 min.
Ultraviolet Light Resistance - % 1/	ASTM D 4355 150 hrs. exposure	70% min. tensile strength retained	70% min. tensile strength retained
Apparent Opening Size (AOS)	ASTM D 4751	As specified or a minimum #100 2/	As specified or a minimum #100 2/
Percent Open Area (percent)	CWO-02215-86 3/	4.0 min.	1.0 min.
Permitivity sec^{-1}	ASTM D 4491	0.10 min.	0.10 min.

1/ Minimum roll value (weakest principal direction): average minus two standard deviations (only 2-1/2 percent will be lower).
2/ U.S. standard sieve size.
3/ Test methods prepared by U.S. Army Corps of Engineers.

TABLE 2 - REQUIREMENTS FOR NONWOVEN GEOTEXTILES BY USE

Property	Test Method	Slope Protection		Subsurface Drainage	Road Stabilization
		Unprotected Class I	Protected/Bedding Class II	Class III	Class IV
Tensile Strength - lbs 1/	ASTM D 4632	180 min.	120 min.	90 min.	115 min.
Bursting Strength - psi 1/	ASTM D 3786	320 min.	210 min.	180 min.	NA
Elongation - % 1/	ASTM D 4632	50 max.	50 max.	50 max.	50 max.
Puncture - lbs. 1/	ASTM D 4833	80 min.	60 min.	40 min.	40 min.
Ultraviolet Light Resistance-% 1/	ASTM D 4355 150 hrs. exposure	70% min. tensile strength retained	70% min. tensile strength retained	70% min. tensile strength retained	70% tensile strength retained
Apparent Opening Size (AOS)	ASTM D 4751	As specified or a maximum #40 2/	As specified or a maximum #40 2/	As specified or a maximum #40 2/	As specified or a maximum #40 2/
Permittivity - $sec.^{-1}$ 1/	ASTM D 4491	0.70 min.	0.70 min.	0.70 min.	0.10 min.

1/ Minimum roll value (weakest principal direction): average minus two standard deviations (only 2-1/2 percent will be lower).
2/ U.S. standard sieve size.

Source:
NRCS Indiana Geotextile
December 1999

APPENDIX D — INDOT COURSE AGGREGATE SIZE SPECIFICATIONS

Sieve Sizes	Coarse Aggregate Sizes (Percent Passing)									
	Coarse Graded								Dense Graded	
	2	5	8	9	11	12	43[1]	91	53[1]	73[1]
4 in. (100 mm)										
3½ in. (90 mm)										
2½ in. (63 mm)	100									
2 in. (50 mm)	80-100									
1½ in. (37.5 mm)		100					100		100	
1 in. (25 mm)	0-25	85-98	100				70-90	100	80-100	100
¾ in. (19 mm)	0-10	60-85	75-95	100			50-70		70-90	90-100
½ in. (12.5 mm)	0-7	30-60	40-70	60-85	100	100	35-50		55-80	60-90
3/8 in. (9.5 mm)		15-45	20-50	30-60	75-95	95-100				
No. 4 (4.75 mm)		0-15	0-15	0-15	10-30	50-80	20-40		35-60	35-60
No. 8 (2.36 mm)		0-10	0-10	0-10	0-10	0-35	15-35		25-50	
No. 30 (600 µm)						0-4	5-20		12-30	12-30
No. 200 (75 µm)[2]							0-6		5-10	5-12

Notes:

[1] The liquid limit shall not exceed 25 (35 if slag) and the plasticity index shall not exceed 5. The liquid limit shall be determined in accordance with AASHTO T 89 and the plasticity index in accordance with AASHTO T 90.

[2] Includes the total amount passing the No. 200 (75 micrometers) sieve as determined by AASHTO T 11 and T 27.

Riprap Gradation Requirements (Percent Smaller)					
Size, in. (mm)	**Revetment**	**Class 1**	**Class 2**	**Uniform A**	**Uniform B**
30 (750)			100		
24 (600)		100	85-100		
18 (450)	100	85-100	60-80		
12 (300)	90-100	35-50	20-40		
8 (200)				100	
6 (150)	20-40	10-30	0-20	35-80	95-100
3 (75)	0-10	0-10	0-10		35-80
1 (25)				0-20	0-20
Depth of Riprap, minimum	18 in. (450 mm)	24 in. (600 mm)	30 in. (750 mm)		

APPENDIX E — READING & UNDERSTANDING FERTILIZER LABELS

Selection and application of fertilizers requires a basic knowledge about how to read and understand fertilizer labels.

Fertilizers come in two forms—chemically based or natural based. Most **chemically based** fertilizers are simple compounds. Nitrogen is synthesized from the atmosphere to create ammonia and urea. Phosphate and potash are obtained from naturally occurring mined deposits that are minimally processed to make the nutrients more available to plants. **Natural based** fertilizers are derived from organic materials such as fish waste, bone meal, or food processing by-products. Natural based fertilizers are low in plant nutrient content and are slower to release their nutrients in a plant-available form.

Understanding Fertilizer Labels

Fertilizers are typically identified with three numbers. These three numbers are generally printed in large, bold characters on the fertilizer container and refer to the percentage of "primary" nutrients, nitrogen (N), phosphate (P), and potassium (K), in the container. For example, a bag of 24-5-11 analysis fertilizer contains 24 percent nitrogen, five percent phosphate and 11 percent potassium. Therefore, a 50-pound bag of 24-5-11 analysis fertilizer would contain 12 pounds of nitrogen, 2.5 pounds of phosphorous, and 5.5 pounds of potassium.

Bag Weight		% of Nutrients		Pounds of Nutrients
50 lbs.	x	0.24	=	12.0 lbs. of nitrogen
50 lbs.	x	0.05	=	02.5 lbs. of phosphate
50 lbs.	x	0.11	=	05.5 lbs. of potassium
				20.0 lbs. (total weight of nutrients)

As illustrated in the above example, the total weight of the nitrogen, phosphate, and potassium will never equal the total weight of the fertilizer container. The remainder of the contents in a fertilizer container is comprised of a mixture of one or more "secondary nutrients" (i.e., calcium, magnesium, and sulfur), "micro-nutrients" or as they are sometimes referred to as "trace" elements, (i.e., boron, chlorine, copper, iron, manganese, molybdenum, and zinc), and a filler material (generally sand or granular limestone).

Calculating Fertilizer Application Rates

Fertilizers are generally applied by the coverage rate listed on the packaging (e.g., 25 lbs./5,000 ft^2) or based on a soil test.

Applying fertilizer according to soil tests usually requires converting the total weight of the nutrients in the bag of fertilizer to lbs./ft^2 because soil test recommendations are typically expressed in terms of lbs./square foot or lbs./1,000 square feet. To calculate the lbs./ft^2, the applicator needs to divide the total weight of each nutrient by the square foot coverage listed on the fertilizer container. For most home use fertilizers, the typical rate of coverage is for an area of 5,000 or 10,000 square feet. In the above example, if the area of coverage for the 50 lb. bag is listed as 10,000 square feet then the amount of each nutrient per square foot would be calculated as follows.

Total Weight of Nutrients		Coverage Area Listed on Bag		Weight of Nutrient per Square Foot
12 lbs.	÷	10,000 ft^2	=	0.0012 lbs. of nitrogen/ft^2
2.5 lbs.	÷	10,000 ft^2	=	0.00025 lbs. of phosphorous/ft^2
5.5 lbs.	÷	10,000 ft^2	=	0.00055 lbs. of potassium/ft^2

The next step is to determine how much fertilizer from the bag needs to be applied based on the soil test. If an applicator wants to fertilize an area that is 40 feet by 60 feet and the soil test for the above example recommends 0.5 lbs. of nitrogen per 1,000 square feet, then the applicator would need to apply 5 lbs. of the fertilizer to the area.

40 ft x 60 ft = 2,400 ft^2

(2,400 ft^2 ÷ 1,000 ft^2) x 0.5 lbs. of nitrogen = 1.2 lbs. of nitrogen

(1.2 lbs. of nitrogen x 50 lb. bag) ÷ 12 lbs. of nitrogen/bag = 5 lbs.

Additional information about reading fertilizer labels, application rates, and timing of application based on land use can be obtained from your local county cooperative extension service. For information, visit the Web at www.ces.purdue.edu/counties.htm.

APPENDIX F — SEED STANDARDS FOR INDIANA

Indiana Code 15-4-1, the Indiana Seed Law, is administered and enforced by the Indiana state seed commissioner (i.e., Indiana state chemist). The state seed commissioner is responsible for product registration and sampling, inspecting, making analysis of, and testing seed to determine compliance with the provisions of the act.

Seed Label Tags

The Indiana Seed Law requires that bags or containers of agricultural seed, lawn seed, and mixtures of seeds over one pound in size have an attached tag specifying the following items.

1. The commonly accepted name of each kind and variety of seed component in excess of five percent that is contained in the package and the percentage by weight of each seed component in order of its predominance. (The variety designation can be omitted if the label states the name of the kind of seed and the words "variety not stated.")
   a. If there is more than one seed component in the package the word "mixture" or the word "mixed" must be shown on the label.
   b. If a mixture of two or more varieties of the same kind of seed is in the package, it may be labeled as "blend."

2. Lot number or other lot identification.

3. Origin (state or country where grown) for all seeds except hybrid corn.

4. Percentage of all weed seeds.

5. Name and rate of occurrence per pound of each kind of restricted noxious weed seed present.

6. Percentage of all other seeds (may be designated as "other crop seeds" or "crop seeds").

7. The percentage of inert matter.

8. For each named agricultural or grass seed:
   a. Percentage of germination, exclusive of hard seed.
   b. Percentage of hard seeds, if present.
   c. Calendar month and year the test was completed to determine such percentages.

9. Name and address of person who labeled the seed or who distributed the seed within the state.

10. For all seed named and treated and requiring a separate label:
    a. A word or statement indicating that the seed has been treated.

b. The commonly accepted coined chemical or abbreviated chemical (generic) name of any applied pesticide.
c. A description of the process or the commonly accepted name of the substance applied if other than a pesticide.
d. If the substance in the amount present with the seed is harmful to human or other vertebrate animals, a caution statement such as "Do Not Use For Food or Feed." The caution for mercurials and similarly toxic substances shall be a poison statement or symbol.

11. For all pre-inoculated seeds, in addition to other labeling requirements:
   a. A word or statement indicating that the seed has been pre-inoculated.
   b. The date beyond which the inoculant is not to be considered effective.

The Indiana Seed Law does not require the labeler to follow any specific format for the required label information. However, the rules and regulations do place restrictions on how such information must be shown. One requirement is that "abbreviations or contractions" of required terms is not permitted. Another requirement is that the omission of any required terms is not permitted. For example, seed that does not contain any "other crop seeds" or "weed seeds" must be labeled as having "0.00 percent" for each of these respective categories. Following is an example of a seed analysis tag.

LOT NO. ________

____
SEEDSMAN NAME

____
ADDRESS

____
CITY STATE ZIP

____
KIND AND VARIETY (or "VARIETY NOT STATED)

Minimum Pure Seed:	____%	**Where Grown:**	____________
Other Crop Seed:	____%	**Weed Seed:**	____%
Inert Matter:	____%	**Noxious Weeds:** (If present, kind and number per pound)	
Minimum Germination:	____%		____________
Hard Seed:	____%		____________
Germination Test:			____________
______ Month	______ Year		____________

Contents of the bag or container are listed in percentages of the total weight of the bag or container.

Lot Number

The "Lot Number" is used for identification purposes and can be used to trace the originator of the seed.

Seedsman Name

"Seedsman Name" identifies the name and address of the person who labeled the seed or who
distributed the seed within the state.

Crop Seed

The percentage of agricultural crop seed or lawn seed is listed for each variety of agricultural or lawn seed contained in the bag or container.

Seed Mixtures

When two or more different kinds of seed, each in excess of five percent by weight, are present in the bag or container, the seed tag must be labeled "Mixture" or "Mixed" to indicate the presence of more than one kind of seed. The percentage, by weight, and the name of each seed component must be listed in order of predominance. The seed tag must also list the separate germination percentage, hard seed percentage (where applicable), and origin for each component of the mixture. Following is an example of a seed mixture seed tag.
Seed mixtures sold under "common kind designations" such as Kentucky bluegrass, perennial ryegrass, and medium red clover must be labeled as "variety not stated" when the seed variety name is not listed on the seed tag.

JOHN DOE SEED COMPANY, INC.
ANYWHERE, INDIANA 47000
"SHADY GRASS SEED MIXTURE" LOT AB1
73.50% BARON KENTUCKY BLUEGRASS GERMINATION 80% WA. GROWN
13.72% PENNLAWN CREEPING RED FESCUE GERMINATION 85% OR. GROWN
10.78% * CHEWINGS FESCUE GERMINATION 85% OR. GROWN
0.09% OTHER CROP SEEDS
1.82% INERT MATTER
0.09% WEED SEEDS
* Variety Not Stated
NOXIOUS WEED SEEDS - NONE
GERM TEST DATE: JAN 1984

Source: Indiana Seedsmen's Handbook (revised January 1987), Office of the Indiana State Seed Commissioner Web site

Example: Medium Red Clover, Lot Number 123
Variety Not Stated

Minimum Pure Seed

"Minimum Pure Seed" lists the total percentage of pure agricultural or lawn seed contained in the bag or container. If the tag lists 99.14 percent pure crop seed and the bag weighs 100 lbs. then 99.14 lbs. of the bag or container must be pure crop seed.

Where Grown

"Where Grown" identifies the state or country where the seed originated.

Other Crop Seed

"Other Crop Seed" identifies the percentage of agricultural or lawn seed not named under "Crop Seed" on the seed analysis tag. For example, if the pure crop seed is medium red clover, then the other crop seed might be another variety of clover or some other crop seed. A low or zero percentage of other crop seed is best.

Inert Matter

The percentage of sand, stones, dirt, sticks, pods, chaff, broken seeds, etc. is listed as inert matter. Inert matter does not grow. A very low percentage of inert matter is desirable.

Germination Test

"Germination Test" identifies the month and year the seed was tested for minimum germination. The seed germination test is valid for a period of up to nine months.

- ### Minimum Germination

  "Minimum Germination" lists the percentage of pure live seed that will produce normal plants under favorable conditions in the field. This percentage is calculated by multiplying the percentage of pure live seed by the percentage of germination.

Example:	Seed analysis tag lists:	92.00% germination 95.50% pure seed 87.86% pure live seed
0.955	(pure seed @ 95.5%)	
x 0. 920	(germination @ 92%)	
0		
19100		
+ 859500		
0.878600		
x 100		
87.86	(pure live seed @ 87.86%)	

Hard Seed

The percentage of hard seed (where applicable) that will germinate is listed under "Hard Seed." Hard seed will not germinate within the germination period of the primary seed in the bag or container because it does not absorb water due to the hard seed coat. Hard seed is undesirable when immediate germination is needed. Conversely, it is desirable when an extended germination period will increase the chances of a good vegetative stand. Hard seed is common in legumes seed such as clovers, alfalfa, etc.

Weed Seeds

Indiana has allowable limits on the percent of certain varieties of weed seeds that can be contained in a bag or container of seed. A zero percentage is best.

Example: The clover seed analysis tag for a 100 lb. bag of clover seed lists:
Pigweed Seed 0.01%

120	(number of pigweed seeds found in one pound of clover seed)
x 100	(lbs. of clover in bag)
12,000	(number of pigweed seeds in a 100-pound bag of clover seed)

1,194,737 (number of pigweed seeds in one pound)

12,000 divided by 1,194,737 = 0.01%

Seeds of plants recognized as weeds by the Indiana Seed Law or U.S. Customs are listed under "Weed Seeds." Section 6 of the Indiana Seed Law [IC 15-4-1-6 (a)(5)] states that it is unlawful to distribute seed within Indiana if:

1. The seed contains or consists of PROHIBITED noxious weed seeds and/or contains RESTRICTED noxious weed seed in excess of 0.25 percent by weight, or
2. The RESTRICTED noxious weed seed is less than 0.25 percent unless the name and number per pound of each RESTRICTED noxious weed seed is listed on the seed tag.

The name and rate of occurrence per pound of each kind of RESTRICTED noxious weed seed is listed under "Noxious Weeds."

Prohibited Noxious Weed Seeds

PROHIBITED noxious weeds are perennial weeds that are extremely difficult to control. Most states prohibit the sale of seed containing PROHIBITED noxious weed seed. Each state has its own specific list of PROHIBITED noxious weed seeds.

APPENDIX F — SEED STANDARDS FOR INDIANA

Indiana has classified the following weeds as either PROHIBITED noxious weeds or RESTRICTED noxious weeds when found in seeds offered for sale. Indiana has other specific laws which deal with illegal propagation and infestation of specific weeds. Local government agencies are generally responsible for enforcing these laws.

Prohibited Noxious Weeds in Indiana	Restricted Noxious Weeds in Indiana
Canada Thistle	Bitter Wintercress
Field Bindweed	Buckhorn
Johnsongrass	Cocklebur
Perennial Peppergrass	Corncockle
Perennial Sowthistle	Curled Dock
Quackgrass	Dodder
Russian Knapweed	Eastern Black Nightshade
Wild Garlic	Field Peppergrass
Wild Onion	Giant Foxtail
	Horsenettle
	Mustard
	Oxeye Daisy
	Pennygrass

Additional Information

Internet Keyword Search:
Indiana Seed Law, Indiana Code 15-4-1; Seed Laws;
Association of Official Seed Analysts

Indiana Resources:
Office of the Indiana State Seed Commissioner
Purdue University
175 South University Street
West Lafayette, Indiana 47907-2063
Telephone: (765) 494-1557
FAX: (765) 496-3967
www.isco.purdue.edu/seed/index_seed.htm

Purdue University Cooperative Extension Service
www.ces.purdue.edu/counties.htm

APPENDIX G — U.S. DEPARTMENT OF AGRICULTURE NATURAL RESOURCES CONSERVATION SERVICE STANDARDS & SPECIFICATIONS FOR SELECTED STORM WATER QUALITY MANAGEMENT MEASURES

This appendix contains reproduced copies of selected storm water management practices contained in the U.S. Department of Agriculture, Natural Resources Conservation Service Field Office Technical Guide. The practices included here were selected based on their ability to manage and treat storm water runoff from construction and post-construction activities.

The practices in this appendix have been included as an alternative to visiting a Natural Resources Soil Conservation/Soil and Water Conservation District office to view the complete Technical Guide which consists of several large binders of materials.

The standards and specifications contained herein are updated periodically and were current at the time of this manual's initial publication. Local Natural Resources Soil Conservation/ Soil and Water Conservation District offices should be contacted when there is a question or concern in regard the current date of a particular practice or practices.

Storm Water Management Practices

- Constructed Wetland
- Diversion
- Filter Strip
- Grade Stabilization Structure
- Grassed Waterway
- Lined Waterway or Outlet
- Mulching
- Pond
- Riparian Forest Buffer
- Sediment Basin
- Streambank and Shoreline Protection
- Stream Channel Stabilization
- Subsurface Drain
- Tree/Shrub Establishment
- Well Decommissioning

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NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

Constructed Wetland

(Acre)

Code 656

DEFINITION

A constructed shallow water ecosystem designed to simulate natural wetlands.

PURPOSES

To reduce the pollution potential of runoff and wastewater from agricultural lands to water resources.

CONDITIONS WHERE PRACTICE APPLIES

- Where a constructed wetland is a component of a planned conservation system or agricultural waste management system
- Where wastewater or runoff originates from agricultural lands including livestock or aquaculture facilities
- Where a constructed wetland can be constructed, operated and maintained without polluting air or water resources

This practice does not apply to:

- wetland restoration (FOTG Standard 657) intended to rehabilitate a degraded wetland where the soils, hydrology, vegetative community, and biological habitat are returned to original conditions
- wetland enhancement (FOTG Standard 659) intended to rehabilitate a degraded wetland where specific functions and/or values are enhanced beyond original conditions
- wetland creation (FOTG Standard 658) for creating a wetland on a site location which historically was not a wetland, or was a wetland with a different hydrology, vegetation type, or functions that occurred naturally on site.

CRITERIA

General Criteria Applicable To All Purposes

Laws and Regulations. All federal, state, and local laws, rules and regulations governing the use of constructed wetlands must be followed. Constructed wetland for waste treatment shall not be designed to discharge to waters of the state unless permitted by state laws and regulations, and appropriate permits have been obtained to do so. In addition, if discharge is permitted, the receiving surface water must have the capacity to assimilate constructed wetland's effluent during low flow periods.

Location: Constructed wetlands shall be located outside the limits of wetlands of any classification

Constructed wetlands located within a floodplain shall be protected from inundation or damage from a 25-year flood event, or larger, if required by laws, rules, and regulations.

Type. Constructed wetlands shall be designed as surface flow systems consisting of adequate seepage control, a suitable plant medium, rooted emergent hydrophytic vegetation, and the structural components needed to contain and control the flow.

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

Indiana NRCS FOTG – December 2001.

Influent. The influent to the constructed wetland shall be pretreated to reduce the concentrations of solids, organics, and nutrients to levels that will be tolerated by wetland plants and not cause excessive accretion within the wetland.

Where significant sediment and organic debris are expected in the wastewater or runoff to be treated, provisions for its entrapment before entry into the wetland must be provided.

Water budget. A water budget that evaluates runoff or wastewater volumes, precipitation, evaporation, and water use shall be used to determine the required hydraulic retention time in the wetland and storage requirements of the wetland pretreatment and post treatment facilities when included.

Embankment. The perimeter embankment shall have a minimum top width of 10 feet. Interior embankments shall have a minimum top width of 8 feet. All embankment side slopes shall be 2 horizontal to 1 vertical or flatter.

The embankments shall be seeded according to Table 1.

Table 1. Seeding mixes for embankments.

Species	PLS Rates/AC
[1,2] Orchardgrass	6
Timothy	2
Annual Lespedeza	4
Ladino Clover	¼
[1] Redtop	2
Orchardgrass	6
Annual Lespedeza	4
Ladino Clover	¼
[1] Redtop	2
Timothy	2
Red Clover	2
Annual Lespedeza	4
Orchardgrass	6
Timothy	2
Alfalfa	6
Ladino Clover	¼
[3] Smooth Brome	10
Alfalfa	6
Ladino Clover	¼
Birdsfoot Trefoil	4
[4] Timothy	2
Smooth Bromegrass	10
Alsike Clover	1
Birdsfoot Trefoil	4
[1] Timothy	2
Ky. Bluegrass	3
Annual Lespedeza	4
Birdsfoot Trefoil	4
Switchgrass	8

Species	PLS Rates/AC
[4] Redtop	2
Timothy	2
Alsike Clover	2
Birdsfoot Trefoil	4
[1] Redtop	2
Ky. Bluegrass	3
Annual Lespedeza	4
Ladino Clover	¼
[1] Orchardgrass	6
Timothy	2
Red Clover	2
Ladino Clover	¼
Annual Lespedeza	4
[3] Smooth Bromegrass	10
Timothy	2
Ladino Clover	¼
Birdsfoot Trefoil	4
[1] Orchardgrass	6
Timothy	2
Red Clover	2
Sweet Clover	3
[1] Timothy	2
Ky. Bluegrass	3
Annual Lespedeza	4
Red Clover	2
Orchard grass	6
Timothy	2
Ladino Clover	¼
Birdsfoot Trefoil	4

[1] Better suited for the Southern part of Indiana
[2] Can be used on droughty sites
[3] Better suited for the Northern part of Indiana
[4] Can be used on wet sites

Indiana NRCS FOTG – December 2001.

Note: 2 to 8 oz of any single or combination of the forb species listed below can be added to any of the above mixtures for added wildlife and aesthetic benefits or substituted for one of the legumes in the mix.

Forb Species

Blackeyed Susan	Illinois Bundle Flower	Stiff Goldenrod
Butterflyweed	New England Aster	Sunflower Heliopsis
Button Blazing Star	Partridge Pea	Tall Coreopsis
Dense Blazing Star	Prairie Dock	Virginia Mountain Mint
Entire-Leaf Rosinwood	Purple Coneflower	Wild Bergamot
Gray-Headed Coneflower	Sawtooth Sunflower	

Vegetation. Vegetation shall be established in wetland cells prior to loading. Vegetation selected for the constructed wetland cells shall be hydrophytic plants suitable for local climatic conditions and tolerant of the concentrations of nutrients, pesticides, and other constituents in the runoff or wastewater stream and selected for their treatment potential.

Preference shall be given to native wetland plants with localized genetic material. Plant materials collected or grown from material collected within a 200-mile radius from the site is considered local. See Table 2 for recommended plants.

Table 2. Recommended Plants

Deep Water Emergent Community (1-3 foot depth)	
Yellow Pond Lily	Nuphar advena
White Water Lily	Nymphaea odorata
Shallow Water Emergent Community (0-1 foot depth)	
Lake Sedge	Carex lacustris
Soft Rush	Juncus effusus
Hardstem Bulrush	Scripus acutus
Woolgrass	Scripus cyperinus
Three-Square Bulrush	Scripus pugens
Softstem Bulrush	Scripus validus
Sweet Flag	Acorus calamus
Pickerel Weed	Pontederia cordata
Common Arrowhead	Sagittaria latifolia
Blue Flag Iris	Iris virginica shrevei
Giant Burreed	Sparganium eurycarpum
Sedge Meadow Community (saturated soils)	
Frank's Sedge	Carex frankii
Bottlebrush Sedge	Carex granularis
Awl-Fruited Sedge	Carex stipata
Tussock Sedge	Carex stricta
Fox Sedge	Carex vulpinoidea
Virginia Wildrye	Elymus virginicus
Rice Cutgrass	Leersia oryzoides
Fowl Manna Grass	Glyceria striata
Switchgrass	Panicum virgatum
Dark Green Bulrush	Scripus atrovirens
Red Bulrush	Scripus pendulus
Swamp Milkweed	Asclepias incarnata
New England Aster	Aster novae-angliae
Swamp Aster	Aster puniceus
Spotted Joe-Pye Weed	Eupatorium maculatum
Boneset	Eupatorium perfoliatum
Autumn Sneezeweed	Helenium autumnale
Cardinal Flower	Lobelia cardinalis
Great Blue Lobelia	Lobelia siphilitica
Obedient Plant	Physostegia virginiana
Riddell's Goldenrod	Solidago riddellii
Blue Vervain	Verbena Hastata

Planting medium. The soil used for the planting medium shall have a cation exchange capacity, pH, electrical conductivity, soil organic matter, and textural class that is conducive to wetland plant growth and retention of contaminants.

Seepage control. The constructed wetland shall be located in soils with a permeability that meets all applicable regulations, or it shall be lined. Measures for controlling seepage shall meet the criteria of Waste Treatment Lagoon (Practice Standard 359), and Waste Storage Structure (Practice Standard 313).

Indiana NRCS FOTG – December 2001.

Livestock shall be excluded from the wetland.

Use Part 637 Environmental Engineering, National Engineering Handbook, Chapter 3 Constructed Wetlands as a guide for design.

Additional Criteria for Waste Treatment

Topography. Site topography shall accommodate the requirements for length to width ratios of the wetland and the wetland cells, and the requirement that the wetland cells be level side to side and grades of less than 0.05 ft/ft lengthwise. The wetland shall have a bottom elevation that is a minimum of 2 feet above the high water table.

Inlet. An inlet structure that will allow control of flow discharged to wetland and separation of solids from influent to prevent debris from entering wetland shall be provided. Design of the inlet structure shall assure its function throughout the life of the wetland considering accretion. The inlet shall be designed to direct or exclude flows to each row of cells. Criteria in NRCS Practice Standard 313, Waste Storage Facility, for fabricated structures shall apply as appropriate.

Influent. Constructed wetlands for wastewater treatment shall not allow for direct inclusion of contaminated and/or uncontaminated runoff.

Wastewater will be of sufficient volume and duration to keep the constructed wetland moist at all times or accommodations shall be made for the addition of supplemental water.

Surface Area. The surface area of the wetland shall be determined using a recognized design procedure in consideration of loading, temperatures, and the desired level of treatment,

Configuration. The constructed wetland shall have an overall length to width ratio of 1:1 to 4:1. Individual cells within the constructed wetland shall have a length-to-width ratio of 10:1 to 15:1. The wetland shall consist of at least two rows of parallel cells.

Flow depth. The design depth shall be based on the most severe season of operation, the desired level of treatment, and the required littoral zone of the plant species being used. The design depth shall be a minimum of 0.33 ft. and a maximum of 1.5 ft.

Embankments. Height of the constructed wetland perimeter embankment shall be the sum of the following:

- Design depth
- Wetland accretion -- a minimum of 1 inch per year for the design life
- 25-year, 24-hour precipitation
- 12 inches of freeboard

The height of wetland's interior embankments shall be the sum of the following:

- Normal design flow depth
- Wetland accretion -- minimum of 1 inch per year for the design life

Overflow Device. An ungated overflow device shall be provided to operate when the 25-year, 24-hour precipitation is exceeded. The overflow device shall operate without infringing on the wetland perimeter embankment's freeboard.

Outlet. Wastewater discharged from the constructed wetland shall be transferred to a waste storage facility, a waste treatment lagoon, or other facility for further treatment and/or utilization unless discharge is permitted by regulations.

An outlet structure shall be provided that allows maintenance of proper water level in the wetland and controls the flow from the wetland.

Additional Criteria For Runoff Treatment

Design Storm. The constructed wetland system shall be designed to contain a 2-year storm runoff. Limited area sites handling only the "first flush" volume shall have a minimum capacity to store 0.5 inch of runoff volume from the entire drainage area. When less than full runoff is stored, bypass of the excess storm flow shall be provided.

Detention time and surface area. The detention time and surface area shall be calculated on the time required to achieve the required level of treatment based on the limiting contaminant present.

Wetland Cells. Length to width ratios are to be 4:1 to 10:1. Other dimensions and shapes that provide a more natural landscape appearance that meet treatment requirements can be used.

The standards and specifications for Dike (FOTG Standard 356) and Structure for Water Control (FOTG Standard 587) will be used as appropriate. Refer to the Engineering Field Handbook, Chapters 13, "Wetland Restoration, Enhancement, and Creation," and 6, "Structures," for additional design information. Existing drainage systems will be utilized, removed, or modified as needed to achieve the intended purpose.

Depth. Maximum water depth shall be 24 inches except in those instances where deep water areas are included as a special design.

Outlet. A water control structure to automatically regulate storage release in accordance with the design detention time shall be installed.

CONSIDERATIONS

Locate constructed wetlands downgrade and as near the source of wastewater as practical.

Constructed wetlands shall be located to provide sufficient separation distances so prevailing winds and landscape elements such as building arrangement, landforms, and vegetation will minimize odors and protect aesthetic values.

Install measures to exclude or minimize attractiveness of the constructed wetland to wildlife that could be adversely affected by the constructed wetland. Take measures to exclude burrowing animals should they frequent the wetland. Consider the use of fences as an exclusion measure and for safety in populated areas.

Recycle constructed wetland effluent back through the agricultural waste management system when practical.

In northern cold climates consideration should be given to storage of wastewater during winter months instead of wetland operation.

PLANS AND SPECIFICATIONS

Plans and specifications shall be prepared in accordance with the criteria of this standard and shall describe the requirements for applying the practice to achieve its intended use. Plans shall include construction sequence, vegetation establishment, and management and maintenance requirements.

OPERATION AND MAINTENANCE

An operation and maintenance plan shall be developed that is consistent with the purposes of the practice, its intended life, safety requirements, and the criteria for its design. Operational requirements should include:

- Control of water level in wetland cells appropriate for vegetation.
- Control flow to wetland according to water budget.
- Monitoring of wetland performance.
- Sampling effluent for nutrients prior to utilization.
- Surveillance of inlet and outlet.

Maintenance requirements should include:

- Repair of embankments.
- Control of wetland vegetation in cells.
- Repair of fences or other ancillary features.
- Replacement of wetland plants.
- Repair of pipelines.
- Control of animals (varmints).
- Maintain vegetation on embankments.
- Manage nutrients

REFERENCES

1. Natural Resources Conservation Service, *Part 637 Environmental Engineering, National Engineering Handbook, Chapter 3 Constructed Wetlands*

2. Environmental Protection Agency Website: www.epa.gov/owow/wetlands/constructed publication *Guiding Principals for Constructed Treatment Wetlands: Providing Water Quality and Wildlife Habitat*

3. Natural Resources Conservation Service, *Engineering Field Handbook, Chapter 13, Wetland Restoration, Enhancement, or Creation*

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

Diversion

(Feet)

Code 362

DEFINITION

A channel constructed across the slope generally with a supporting ridge on the lower side.

PURPOSES

This practice may be applied as part of a resource management system to support one or more of the following purposes.

- Break up concentrations of water on long slopes, on undulating land surfaces, and on land that is generally considered too flat or irregular for terracing.
- Divert water away from farmsteads, agricultural waste systems, and other improvements.
- Collect or direct water for water-spreading or water-harvesting systems.
- Increase or decrease the drainage area above ponds.
- Protect terrace systems by diverting water from the top terrace where topography, land use, or land ownership prevents terracing the land above.
- Intercept surface and shallow subsurface flow.
- Reduce runoff damages from upland runoff.
- Reduce erosion and runoff on urban or developing areas and at construction or mining sites.
- Divert water away from active gullies or critically eroding areas.

Supplement water management on conservation cropping or stripcropping systems.

CONDITIONS WHERE PRACTICE APPLIES

This applies to all cropland and other land uses where surface runoff water control and or management is needed. It also applies where soils and topography are such that the diversion can be constructed and a suitable outlet is available or can be provided.

CRITERIA

Criteria Applicable to All Purposes.

Diversions shall be planned, designed, and constructed to comply with all Federal, State, and local laws and regulations.

Capacity. Diversions as temporary measures, with an expected life span of less than 2 years, shall have a minimum capacity

for the peak discharge from the 2-year frequency, 24-hour duration storm.

Diversions that protect agricultural land shall have a minimum capacity for the peak

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

discharge from a 10-year frequency, 24-hour duration storm.

Diversions designed to protect areas such as urban areas, buildings, roads, and animal waste management systems shall have a minimum capacity for the peak discharge from a storm frequency consistent with the hazard involved but not less than a 25-year frequency, 24-hour duration storm. Freeboard shall be at least 0.3 ft.

Design depth is the channel storm flow depth plus freeboard.

Cross section. The channel shall be either parabolic, V-shaped or trapezoidal. The diversion shall be designed to have stable side slopes. The side slopes shall be no steeper than 2:1.

The ridge shall have a minimum top width of 4 feet at the design depth. The ridge height shall include an adequate settlement factor with a minimum of 10 percent.

The top of the constructed ridge at any point shall not be lower than the design depth plus the specified overfill for settlement.

The design depth at culvert crossings shall be the culvert headwater depth for the design storm plus freeboard.

Grade and Velocity. Channel grades and velocities shall not exceed that considered non-erosive for the soil and planned vegetation or lining.

Maximum channel velocities for permanently vegetated channels shall not exceed those recommended in the NRCS Engineering Field Handbook (EFH) Part 650, Chapter 9, Table 9-1, or Agricultural Research Service (ARS) Agricultural Handbook 667, Stability Design of Grass-Lined Open Channels (Sept. 1987).

When the capacity is determined by the formula Q = A V and the V is calculated by using manning's equation, the highest expected value of "n" shall be used.

Location. The outlet conditions, topography, land use, cultural operations, cultural resources, and soil type shall determine the location of the diversion. A diversion in a cultivated field must be aligned to permit use of modern farming equipment.

Protection Against Sedimentation. Diversions are not normally used below high sediment producing areas. When they are, a practice or combination of practices, needed to prevent damaging accumulations of sediment in the channel shall be installed. This includes practices such as land treatment erosion control practices, cultural or tillage practices, vegetated filter strip, or structural measures. Install practices in conjunction with or before the diversion construction.

If movement of sediment into the channel is a problem, the design shall include extra capacity for sediment or periodic removal as outlined in the operation and maintenance plan.

Outlets. Each diversion must have a safe and stable outlet with adequate capacity. The outlet shall be a grassed waterway, a lined waterway, a vegetated or paved area, a grade stabilization structure, an underground outlet, a stable watercourse, a sediment basin, or a combination of these practices. The outlet must convey runoff to a point where outflow will not cause damage. Vegetative outlets shall be installed and established before diversion construction to ensure establishment of vegetative cover in the outlet channel.

The release rate of an under ground outlet, when combined with storage, shall be such that the design storm runoff will not overtop the diversion ridge.

The design depth of the water surface in the diversion shall not be lower than the design elevation of the water surface in the outlet at their junction when both are operating at design flow.

Temporary Diversions. Temporary diversions shall be used where their life expectancy is less than two years. They shall be used above newly constructed slopes and across graded right-of-way to intercept and divert storm runoff. Temporary diversions shall be planned and installed to be stable through their useful life and shall meet the following criteria:

1. Drainage areas shall not exceed three acres.
2. The minimum cross section will be as follows:

Top Width	Height	Side Slopes
0	1 ft. Min.	4:1 or Flatter
4	1 ft. Min.	2:1 or Flatter

Vegetation. Disturbed areas that are not to be cultivated shall be seeded as soon as practicable after construction.

If needed, apply lime to raise the pH to the level desired for species of vegetation being seeded.

Fertilize according to soil tests or at a minimum rate of 500 lbs. of 12-12-12 fertilizer, or its equivalent, per acre as soon as the diversion has been constructed. Seed during the preferred seeding periods of March 1 to May 10 or August 1 to September 30. Establish vegetation as soon as conditions permit. Seed with one of the mixes in Table 1.

Seed during the preferred seeding periods of March 1 to May 10 or August 1 to September 30. Establish vegetation as soon as conditions permit.

Lining. If the soils or climatic conditions preclude the use of vegetation for erosion protection, non-vegetative linings such as gravel, rock riprap, cellular block, or other approved manufactured lining systems shall be used.

The following species may be added for additional wildlife value.

Partridge pea	2 Lbs./ac.	
Annual Lespedeza	2 Lbs./ac.	South of I-70 Spring seed only.
Ladino Clover	0.25 lb./ac.	
Timothy	1 lb./ac.	

TABLE 1

Mixes	Lbs. Of PLS*/acre	Comments
Tall Fescue	35	Fits most situations.
Creeping Red Fescue Kentucky Bluegrass	12 10	Shady sites, low velocity sites.
Kentucky Bluegrass	45	Low velocity sites.
Orchardgrass Perennial Ryegrass	10 8	PRG** for quick establishment Orchardgrass may take two years to establish.
Orchardgrass Redtop	8 3	Redtop for quick establishment Best seeded in spring.
Switchgrass Redtop	8 1.5	Seed before June 30. 10 acre maximum watershed.
Redtop	8	Quick establishment, low fertility sites.
Orchardgrass Timothy Perennial Ryegrass	6 3 4	PRG** for rapid growth. Best seeded in the fall.
Timothy Perennial Ryegrass Tall Fescue	4 8 6	Best seeded in the fall.

*Pure Live Seed ** Perennial Ryegrass

Note: Switchgrass / Redtop mix should be seeded only in the spring and only on diversions with drainage areas of 10 acres or less.

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

CONSIDERATIONS

A diversion in a cultivated field should be aligned and spaced from other structures or practices to permit use of modern farming equipment. The side slope lengths should be sized to fit equipment widths when cropped.

At non-cropland sites, consider planting native vegetation in areas disturbed due to construction.

To reduce the risk of vegetative failure use mulch or erosion control blankets to protect the soil until vegetation is established. Refer to the Natural Resources Conservation Service (NRCS) Field Office Technical Guide (FOTG) Standard 484, Mulching, for guidance on materials, quantities and techniques for mulching and erosion control blankets.

Maximize wetland functions and values with the diversion design. Minimize adverse effects to existing functions and values. Diversion of upland water to prevent entry into a wetland may convert a wetland by changing the hydrology. Any construction activities should minimize disturbance to wildlife habitat. Opportunities should be explored to restore and improve wildlife habitat, including habitat for threatened, endangered, and other species of concern.

PLANS AND SPECIFICATIONS

Plans and specification for installing diversions shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

OPERATION AND MAINTENANCE

An operation and maintenance plan shall be prepared for use by the client. The plan shall include specific instructions for maintaining diversion capacity, storage, ridge height, and outlets.

The minimum requirements to be addressed in the operation and maintenance plan are:

1. Provide periodic inspections, especially immediately following significant storms.
2. Promptly repair or replace damaged components of the diversion as necessary.
3. Maintain diversion capacity, ridge height, and outlet elevations especially if high sediment yielding areas are in the drainage area above the diversion. Establish necessary cleanout requirements.
4. Each inlet for underground outlets must be kept clean and sediment buildup redistributed so that the inlet is at the lowest point. Inlets damaged by farm machinery must be replaced or repaired immediately.
5. Redistribute sediment as necessary to maintain the capacity of the diversion.
6. Vegetation shall be maintained and trees and brush controlled by hand, chemical and/or mechanical means.
7. Keep machinery away from steep sloped ridges. Keep equipment operators informed of all potential hazards.
8. Do not graze diversion during establishment and when soil conditions are wet.
9. Protect diversion from damage by farm equipment and vehicles. Do not use diversions as a roadway and practice care when crossing to prevent tillage marks or wheel tracks.
10. Mow diversion as needed to maintain a healthy, vigorous sod. Time the first mowing after nesting birds have hatched (about July 15). Remove excess top growth. Do not burn or overgraze.

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

REFERENCES

NRCS Engineering Field Handbook Part 650, Chapter 9. Diversions, 1986.

NRCS Engineering Field Handbook Part 650, Chapter 7. Grassed Waterways, 1986.

Agricultural Research Service, Agricultural Handbook 667, Stability Design of Grass-lined Open Channels.

NRCS, NHCP Practice Standard, Diversion Code 362.

Indiana NRCS Field Office Technical Guide, Practice Standard, Grassed Waterway Code 412.

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

Indiana NRCS FOTG, April 2003

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NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

Filter Strip

(Acre)

Code 393

DEFINITION

A strip or area of herbaceous vegetation situated between cropland, grazing land, or disturbed land (including forest land) and environmentally sensitive areas.

PURPOSES

1. To reduce sediment, particulate organic matter, and sediment adsorbed contaminant loading in runoff.

2. To reduce dissolved contaminant loading in runoff.

3. To reduce sediment, particulate organic matter, and sediment adsorbed contaminant loading in surface irrigation tailwater.

4. To serve as Zone 3 of a Riparian Forest Buffer, Practice Standard 391.

5. To restore, create or enhance herbaceous habitat for wildlife and beneficial insects.

6. To maintain or enhance watershed functions and values.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies (1) in areas situated below cropland, grazing land, or disturbed land (including forest land) (2) where sediment, particulate organic matter and/or dissolved contaminants may leave these areas and are entering environmentally sensitive areas; (3) in areas where permanent vegetative establishment is needed to enhance wildlife and beneficial insects, or maintain or enhance watershed function. This practice applies when planned as part of a conservation management system.

This practice does not apply to areas subject to long duration flooding, typically greater than 45 days during spring or summer. Sites where it is historically difficult to maintain a stand of perennial grasses or legumes due to frequency or timing of flooding should be planned for a riparian buffer.

CRITERIA

General criteria applicable to all purposes

Filter strips shall be designated as vegetated areas to treat runoff and are not part of the adjacent cropland rotation.

Overland flow entering the filter strip shall be primarily sheet flow. Concentrated flow shall be dispersed by grading or shaping to assure sheet flow.

Prevent erosion where filter strips outlet into streams or channels

Do not use the filter strip as a roadway.

Filter strip establishment shall comply with local, state and federal regulations.

Additional criteria to reduce sediment, particulate organic matter, and sediment adsorbed contaminant loading in runoff

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

The minimum flow length for this purpose shall be 20 feet. Flow length may be increased to meet other resource needs.

Filter strip location requirements:

The filter strip shall be located along the downslope edge of a field or disturbed area. The average watershed slope above the filter strip shall be greater than 0.5% but less than 10%.

The average annual sheet and rill erosion rate above the filter strip shall be less than 10 tons per acre per year.

The filter strip shall be established to permanent herbaceous vegetation consisting of a single species or a mixture of grasses, legumes and/or other forbs adapted to the soil, climate, and nutrients, chemicals, and practices used in the current management system.

For herbaceous cover establishment, refer to Table 1 for Purposes 1, 2, and 3 and Table 2 for Purposes 4, 5, and 6.

Additional criteria to reduce dissolved contaminants in runoff

This criteria supplements "Additional criteria to reduce sediment, particulate organic matter, and sediment adsorbed contaminant loading in runoff".

Filter strip flow length required to reduce dissolved contaminants in runoff shall be based on management objectives, contaminants of concern, and the volume of runoff from the filter strip's drainage area compared with the filter strip's area and infiltration capacity.

The flow length determined for this purpose shall be in addition to the flow length determined for reducing sediment, particulate organic matter, and sediment adsorbed contaminant loading in runoff. The minimum flow length for this purpose shall be 30 feet. Flow length may be increased to meet other resource needs.

Additional criteria to serve as Zone 3 of a Riparian Forest Buffer, Practice Standard 391

Except for the location requirements, the criteria given in "Additional criteria to reduce sediment, particulate organic matter, and sediment adsorbed contaminant loading in runoff" also apply to this purpose.

If concentrated flows entering Zone 3 are greater than the filter strip's ability to disperse them, other means of dispersal, such as spreading devices, must be incorporated.

Additional criteria to reduce sediment, particulate organic matter, and sediment adsorbed contaminant loading in surface irrigation tailwater

Filter strip vegetation may be a small grain or other suitable annual with a plant spacing that does not exceed 4 inches.

Filter strips shall be established early enough prior to the irrigation season so that the vegetation can withstand sediment deposition from the first irrigation.

The flow length shall be based on management objectives.

Additional criteria to restore, create, or enhance herbaceous habitat for wildlife and beneficial insects

If this purpose is intended in combination with one or more of the previous purposes, then the minimum criteria for the previous purpose(s) must be met. Additional filter strip flow length devoted to this purpose must be added to the length required for the other purpose(s).

Any addition to the flow length for wildlife or beneficial insects shall be added to the downhill slope of the filter strip. Vegetation to enhance wildlife may be added to that portion of the filter strip devoted to other purposes to the extent they do not detract from its primary functions.

Plant species selected for this purpose should be selected from Table 2 for permanent vegetation adapted to the wildlife or beneficial insect population(s) targeted.

If this is the only purpose, filter strip width and length shall be based on requirements of the targeted wildlife or insects. Density of the vegetative stand established for this purpose shall consider targeted wildlife habitat requirements and encourage plant diversity. Dispersed woody vegetation shall be used to the extent it does not interfere with herbaceous vegetative growth, or operation and maintenance of the filter strip.

The filter strip shall not be mowed during the nesting season of the target wildlife.

Livestock and vehicular traffic in the filter strip shall be excluded during the nesting season of the target species.

Additional criteria to maintain or enhance watershed functions and values

Filter strips shall be strategically located to enhance connectivity of corridors and non-cultivated patches of vegetation within the watershed.

Filter strips shall be strategically located to enhance aesthetics of the watershed.

Plant species selected for this purpose shall be for establishment of permanent vegetation.

SEEDING MIXTURES FOR FILTER STRIPS

Instructions: Select one grass mix according to the purpose and add one legume at the rate indicated or two legumes at half the rate. Forbs can be added if desired for extra wildlife benefits.

Table 1. Seeding Mixtures for Purposes 1 to 3.

Grass Mix	Rate (lbs/PLS*/Ac)	Seeding Dates
Switchgrass [1/] Redtop	8 0.5	Frost Seed [2/] April 15 to June 1
Orchardgrass Low Endophyte Tall Fescue	5 10	March 1 to May 1 August 1 to September 15
Orchardgrass Timothy	8 1	March 1 to May 1 August 1 to September 15
Orchardgrass Redtop	6 2	March 1 to May 1
Tall Fescue	25	March 1 to May 1 August 1 to September 15
Smooth Brome	40	February 1 to May 1 August 1 to September 15

[1/] Use 20 foot cool season grass (CSG) strip on the side with highest contaminant load except where filter strip will be shaded.
[2/] Frost seed by broadcasting switchgrass into thin wheat nurse crop, bean stubble, or disturbed corn stalks. Frost seeding should be completed by February 20th south of US 40 and by March 15th north of US 40 to assure adequate soil heaving for good seed to soil contact.

Indiana NRCS FOTG – April 2000.

Legumes	Rate (lbs/PLS*/Ac)	Seeding Dates
Annual Lespedeza[1/]	4	Frost Seed [2/] March 15 to May 1
Red Clover	4	Frost Seed [2/] March 15 to May 1 August 1 to September 1
Alsike Clover	1.5	Frost Seed [2/] March 15 to May 1 August 1 to September 1
Ladino Clover	1	Frost Seed [2/] March 15 to May 1 August 1 to September 1

[1/] South of US 40, can be used with either warm season grasses (WSG's) or CSG's.
[2/] Frost seed by broadcasting legumes into thin wheat nurse crop, bean stubble, or disturbed corn stalks. Frost seeding should be completed by February 20th south of US 40 and by March 15th north of US 40 to assure adequate soil heaving for good seed to soil contact.

Table 2. Seeding Mixtures for Purposes 4 to 6.

Grass Mix	Rate (lbs/PLS*/Ac)	Seeding Dates
Switchgrass	5	Frost Seed [2/] April 15 to June 1
Smooth Brome Timothy	10 1	February 1 to May 1 August 1 to September 15
Switchgrass Redtop	3 0.5	Frost Seed [2/] April 15 to June 1
Orchardgrass Timothy	4 0.5	March 1 to May 1 August 1 to September 15
Orchardgrass Redtop	4 0.5	March 1 to May 1
Orchardgrass Kentucky Bluegrass	4 1	March 1 to May 1 August 1 to September 15
Orchardgrass Virginia Wildrye	4 4	March 1 to May 1 August 1 to September 15
Orchardgrass Timothy Redtop	3 0.5 0.5	March 1 to May 1 August 1 to September 15
Little Bluestem [1/]	6	April 15 to June 1
Little Bluestem [1/] Sideoats Grama	4 1.5	April 15 to June 1

[1/] These seeding mixtures have a flooding tolerance of three days or less.
[2/] Frost seed by broadcasting switchgrass into thin wheat nurse crop, bean stubble, or disturbed corn stalks. Frost seeding should be completed by February 20th south of US 40 and by March 15th north of US 40 to assure adequate soil heaving for good seed to soil contact.

Legumes	Rate (lbs/PLS*/Ac)	Seeding Dates
Annual Lespedeza[1/]	4	Frost Seed [2/] March 15 to May 1
Red Clover	4	Frost Seed [2/] March 15 to May 1 August 1 to September 1
Alsike Clover	1.5	Frost Seed [2/] March 15 to May 1 August 1 to September 1
Ladino Clover	1	Frost Seed [2/] March 15 to May 1 August 1 to September 1
Sweet Clover	4	Frost Seed [2/] March 15 to May 1
Alfalfa	5	March 1 to May 1 August 1 to September 1

[1/] South of US 40, can be used with either WSG's or CSG's.

[2/] Frost seed by broadcasting legumes into thin wheat nurse crop, bean stubble, or disturbed corn stalks. Frost seeding should be completed by February 20th south of US 40 and by March 15th north of US 40 to assure adequate soil heaving for good seed to soil contact.

*To figure percent Pure Live Seed (PLS) rates, multiply the percent purity by the percent germination. Divide the seeding rate by the %PLS to find the bulk seed needed per acre. Example: 98% Purity X 60% Germination = .588 PLS, 10 pounds seed per acre/.588 PLS = 17 pounds of bulk seed per acre.

CONSIDERATIONS

Determine landowner's objectives.

Establish filter strips as a component of an overall conservation management system.

Evaluate the type and quantity of pollutant(s).

Determine soil types and slopes.

Estimate average ground water depth.

Determine noxious weed pressure.

Determine fire hazard and other special needs.

Filtering benefits are generally maximized within a 100-foot flow length.

Filter strips established on slopes less than 5 percent are most effective. Steeper slopes require a greater area and width. Filter strips may lose significant effectiveness on slopes greater than 10 percent.

Filter strips should be strategically located to reduce runoff, and increase infiltration and ground water recharge throughout the watershed.

Filter strips for the single purposes of wildlife/beneficial insect habitat or to enhance watershed function should be strategically located to intercept contaminants thereby enhancing the water quality of the watershed.

To avoid damage to the filter strip consider using vegetation that is somewhat tolerant to herbicides used in the watershed. Check recent herbicide use for possible carryover.

Consider using this practice to enhance the conservation of declining species of wildlife, including those that are threatened or endangered.

Consider using this practice to protect National Register listed or eligible (significant) archaeological and traditional cultural properties from potential damaging contaminants.

Filter strip size should be adjusted to a greater flow length to accommodate harvest and maintenance equipment.

Preferred seeding method for Purposes 1 - 3: Broadcast the seed after tilling and culti-packing twice. The seed should be packed in with another pass of the culti-packer. A brillion seeder or similar implement would also be acceptable. A drill, no-till or conventional, is acceptable but not preferred. Drills have 5" to 10" of space between the rows. Grass stands thus established may not be as effective in filtering as those established by broadcast methods or with a brillion type seeder.

A warm season grass drill is the preferred method for establishing warm season grasses for any of the purposes. It is designed to seed the light, fluffy warm season grass seed. Broadcasting warm season grasses often results in failure as the seeds may be planted too deep. (Switchgrass is an exception. It may be seeded with conventional equipment or may be broadcast.)

A no-till or conventional drill is an acceptable method of seeding for Purposes 4 - 6.

PLANS AND SPECIFICATIONS

Based on this standard, plans and specifications shall be prepared for each specific field site where a filter strip will be installed. A plan includes information about the location, construction sequence, vegetation establishment, and management and maintenance requirements.

Specifications will include:

1. Length, width, and slope of the filter strip to accomplish the planned purpose (length refers to flow length across the filter strip).
2. Species selection and seeding or sprigging rates to accomplish the planned purpose.
3. Planting dates, care, and handling of the seed to ensure that planted materials have an acceptable rate of survival.
4. A statement that only viable, high quality, and regionally adapted seed will be used.
5. Site preparation sufficient to establish and grow selected species.

OPERATION AND MAINTENANCE

For the purposes of filtering contaminants, permanent filter strip vegetative plantings should be harvested as appropriate to encourage dense growth, maintain an upright growth habit, and remove nutrients and other contaminants that are contained in the plant tissue. Warm season grasses should not be mowed closer than 10 inches and cool season grasses should not be mowed closer than 6 inches.

Control undesired weed species, especially state-listed noxious weeds.

Prescribed burning may be used to manage and maintain the filter strip when an approved burn plan has been developed.

Inspect the filter strip after storm events and repair any gullies that have formed, remove unevenly deposited sediment accumulation that will disrupt sheet flow, re-seed disturbed areas, and take other measures to prevent concentrated flow through the filter strip.

Apply supplemental nutrients only as needed to maintain the desired species composition and stand density of the filter strip.

To maintain or restore the filter strip's function, periodically re-grade the filter strip area when sediment deposition at the filter strip-field interface jeopardizes its function, and then reestablish the filter strip vegetation, if needed. If wildlife habitat is a purpose, destruction of vegetation within the portion of the strip devoted to that purpose should be minimized by re-grading only to the extent needed to remove sediment and fill concentrated flow areas.

Grazing shall not be permitted in the filter strip unless a controlled grazing system is being implemented. Grazing will be permitted under a controlled grazing system only when soil moisture conditions support livestock traffic without excessive compaction. Warm season grasses should not be grazed closer than 10 inches and cool season grasses should not be grazed closer than 6 inches.

Redistribute organic wastes that accumulate in the filter strip to minimize damage to the vegetation.

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NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

Grade Stabilization Structure

(Number)

Code 410

DEFINITION

A structure used to control the channel grade in natural or constructed watercourses.

PURPOSES

To stabilize grade, reduce gully erosion and/or improve water quality.

CONDITIONS WHERE PRACTICE APPLIES

In areas where the concentration and flow velocity of water requires structures to stabilize the channel grade or to control gully erosion. This practice does not apply to structural inlets to sink holes.

CRITERIA

General criteria. Planned work shall comply with all federal, state and local laws and regulations.

The structure shall be designed for stability after installation. The crest of the inlet shall be set at an elevation that stabilizes the upstream head cutting. The outlet of the structure shall be such that there is minimum erosion at the outlet.

Earth embankments and emergency spillways of structures for which criteria are not provided under the standard for ponds (NRCS Practice Code 378) or floodwater retarding dam (NRCS Practice Code 402), must be stable for all anticipated conditions. If earth spillways are used, they must be designed to handle the total capacity flow indicated in Tables 2 or 4 without overtopping the embankment. The foundation preparation, compaction, top width, and side slopes must ensure a stable embankment for anticipated flow conditions. Discharge from the structure shall be controlled to minimize crop damage resulting from flow detention.

Sediment storage capacity shall equal the expected life of the structure, unless a provision is made for a periodic cleanout.

The structures, earthfill, vegetated spillways, and other areas shall be fenced as necessary to protect the structure. Precautions shall be taken to prevent serious injury or loss of life. Protective guardrails, warning signs, fences, or lifesaving equipment shall be added as needed.

The exposed surfaces of the embankment, earth spillway, borrow area, and other areas disturbed during construction shall be seeded, or sodded or otherwise protected as necessary to prevent erosion.

Embankment dams. Class (a) dams having a product of storage times the effective height of the dam of less than 3,000 ac-ft^2 and an effective height of 35 ft. or less shall meet or exceed the requirements specified for ponds (NRCS Practice Code 378). Principal and emergency spillway capacity requirements shall meet or exceed Table 1.

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

Class (a) dams having a product of storage times the effective height of the dam of 3,000 ac-ft^2 or more, those more than 35 ft. in effective height, and all class (b) and class (c) dams shall meet or exceed the hydrologic, hydraulic, and embankment requirements specified in NRCS Technical Release No. 60, Earth Dams and Reservoirs (TR-60) Revised Oct. 1985.

Pond size dams. If principal spillways are required, the minimum capacity of the principal spillway shall be that required to pass the peak flow expected from a 24-hour duration design storm of the frequency shown in Table 1, less any reduction attributed to detention storage. Detention storage is the volume between the normal pool elevation and the crest of the emergency spillway.

If (1) the effective height of the dam is less than 20 feet and (2) the emergency spillway has a stable grade throughout its length, with no overfalls, and good vegetation along its reentry into the downstream channel, then the principal spillway capacity may be reduced. However, the principal spillway capacity can be no less than 80 percent of the 2-year frequency, 24-hour duration storm as indicated by footnote 3 in Table 1.

Grade stabilization structures with a settled fill height of less than 15 ft. and a 10-year frequency, 24-hour storm runoff of less than 10 acre-ft, shall be designed to control the 10-year frequency storm without overtopping. The principal spillway, regardless of size, shall be considered in design and an emergency spillway is not required if the combination of storage and principal spillway discharge will handle the total design storm. The embankment can be designed to meet the standard for water and sediment control basins (NRCS Practice Code 638) rather than the requirements for ponds (NRCS Practice Code 378).

Table 1. Design Criteria for Dams with Storage Capacity

Limiting Factors			Frequency of Minimum Design Design Storm, years 24-Hour Duration Peak Flow	
Maximum Drainage Area (Acres)	Maximum Effective Height of Dam 5/ (Feet)	Storage Capacity 6/ (Ac-Ft)	Principal Spillway Capacity 1/	Total Capacity 2/
100	<20	Less than 50	2 3/	10
320	<20	Less than 50	5 3/	25
<640	<20	50 or greater	10	50
All others			50% pmp 4/	

1/ To below emergency spillway crest.

2/ Before overtopping the lowest part of earth embankment portion of structure. Total Capacity = Principal Spillway Capacity + Emergency Spillway Capacity + Freeboard.

3/ Can be reduced to 80% of a 2-year frequency if emergency spillway has stable, well vegetated outlet with no overfalls.

4/ Based on a 6-hour probable maximum precipitation (pmp) storm as required by IDNR.

5/ The effective height of the dam is the difference in elevation, in feet, between the emergency spillway crest and the lowest point in the cross section taken along the centerline of the dam. If there is no emergency spillway, the top of the dam is the upper limit.

6/ Storage is the total volume of storage available below the emergency crest elevation or top of fill elevation if there is no emergency spillway.

Full-flow open structures. Full-flow open structures are those which shall pass the design storm through the principal and emergency spillways without creating storage above the design flow's normal depth.

Drop, chute, and box inlet drop spillways shall be designed according to the principles set forth in the Engineering Field Manual for Conservation Practices, the National Engineering Handbook, and other applicable NRCS publications and reports. The minimum capacity shall be that required to pass the peak flow expected from a design storm of the frequency and duration shown in Table 2. Structures must not create unstable conditions upstream or downstream. Provisions must be made to insure reentry of bypassed storm flows.

Table 2. Design criteria for establishing minimum capacity of full-flow open structures.

Maximum drainage area (acres)	Vertical drop (feet)	Frequency of minimum design, 24-hour duration storm peak flow	
		Principal spillway capacity 2/ (year)	Total capacity 3/ (year)
320	5 or less	5 1/	10
640	10 or less	10	25
All others		25	100

1/ Rock chutes, grouted rock chutes, block chutes, concrete chutes and reinforced vegetated chutes shall be designed to carry a 10-year storm as a minimum unless it can be shown that allowable design velocities will not be exceeded should the head water reach the maximum freeboard level. If the minimum design capacity exceeds the downstream channel, then the capacity may be reduced to be equal with the downstream channel.

2/ To below emergency spillway crest.

3/ Before overtopping the lowest part of earth embankment portion of structure. Total Capacity = Principal Spillway Capacity + Emergency Spillway Capacity + Freeboard.

Table 3. Minimum Capacity for Drop Boxes to Culverts

Box Inlet or Riser to Existing Road Culvert	
Condition	Design Capacity
Culvert capacity less than Q_{50}	1.25 culvert capacity
Culvert capacity greater than Q_{50}	Culvert capacity not to exceed 1.5 Q_{50}

Table 4. Design Criteria for Establishing Minimum Capacity of Side Inlet, Open Weir or Pipe Drop Drainage Structures [1]/

Limiting Factors			Minimum Design Storm 24-Hour Duration Years	
Maximum Drainage Area, Acres	Vertical Drop, [5/] Feet	Receiving Channel Depth, [6/] Feet	Principal Spillway [2/] Capacity [3/]	Total Capacity [4/]
320	0-5	0-10	2	5
320	5-10	10-20	5	10
640	0-10	0-20	10	25
All Others	All	All	25	50

1/ For structures outletting into a drainage channel whose drainage area is at least two times the structure drainage area and the channel frequently runs bank full. This table does not apply to rock chutes, grouted rock chutes, block chutes, concrete chutes and reinforced vegetated chutes.
2/ To auxiliary or emergency spillway.
3/ B drainage curve capacity may be used if average watershed slope for side inlet structure is less than 1.0%.
4/ Before overtopping earth embankment portion of structure. Total Capacity = Principal Spillway Capacity + Emergency Spillway Capacity + Freeboard.
5/ Controlled drop in grade.
6/ From low bank to channel grade.

Toe wall drop structures can be used if the vertical drop is 4 ft. or less, flows are intermittent, downstream grades are stable, and tail water depth at design flow is equal to or greater than one-third of the height of the overfall.

The ratio of the capacity of drop boxes to new or existing road culverts shall be as required by the responsible road authority or as specified in Tables 2, 3 or 4, whichever is greater.

Island-type structures. If the principal spillway is designed as an island-type structure, its minimum capacity shall equal the capacity of the downstream channel. The structural spillway shall carry at least the 2-year, 24-hour storm or the design drainage curve runoff. The minimum emergency spillway capacity shall be that required to pass the peak flow expected from a design storm of the frequency and duration shown in Table 2 for total capacity without exceeding the capacity of the structural spillway. Provisions must be made for safe reentry of bypassed flow in excess of the design capacity as necessary.

Side-inlet drainage structures. The design criteria for minimum capacity of open-weir or pipe structures used to lower surface water from field elevations or lateral channels into deeper open channels are shown in Table 4.

Side inlet conduits are to meet the principal spillway thickness and fill height over the pipe conduit requirements of the Standards and Specifications for Pond (NRCS Practice Code 378). Protection against seepage shall be provided. This may be provided by the use of an anti-seep diaphragm, anti-seep collar or toe plate extension on flared inlets. Site conditions may limit anti-seep diaphragms to the bottom half only.

Freeboard of one foot shall be provided over the side inlet conduit where no emergency spillway is provided. Where an emergency spillway is provided, one half foot of freeboard is required, with a minimum total difference of one foot between crest of emergency spillway and top of fill over the conduit

CONSIDERATIONS

In highly visible, public areas and those associated with recreation, careful considerations should be given to landscape resources. Landforms, structural materials, water elements, and plant materials should visually and functionally complement their surroundings. Excavated material and cut slopes should be shaped to blend with the natural topography. Shorelines can be shaped and islands created to add visual interest and valuable wildlife habitat. Exposed concrete surfaces may be formed to add texture or finished to reduce reflection and to alter color contrast. Site selection can be used to reduce adverse impacts or create desirable focal points.

Consideration should be given to the effect a structure will have on the aquatic habitat of a channel. If the channel supports fish, the effect of a structure on the passage of fish should be considered.

Structures installed in natural channels should be compatible with the fluvial geomorphic conditions at the site to ensure the stability of the structure.

PLANS AND SPECIFICATIONS

Plans and specifications for installing grade stabilization structures shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

Vegetative establishment. A protective cover of vegetation shall be established on all exposed surfaces of the embankment, spillway, borrow area and disturbed areas if soil and climatic conditions permit. Temporary vegetation may be used until permanent vegetation can be established.

If needed, apply lime to raise the pH to the level desired for the species of vegetation being seeded.

Fertilize, at the time of seeding, according to soil tests or at a minimum rate of 500 lbs. of 12-12-12 fertilizer, or its equivalent, per acre

Use the grassed waterway seeding mix around the structure site when built in association with the grassed waterway.

Use one of the following mixes when not using the grassed waterway (NRCS Practice Code 412) mix.

Mixes	Lbs. Of PLS*	Comments
Tall Fescue	35	Fits most situations.
Creeping Red Fescue Kentucky Bluegrass	12 10	Shady sites, low velocity sites.
Timothy Perennial Ryegrass Tall Fescue	4 8 6	Best seeded in the fall.

* Pure Live Seed

Seed during the seeding periods of March 1 to May 10 or August 10 to September 30. Establish vegetation as soon as conditions permit. Use straw mulch, filter fences, or nurse crop to protect the vegetation until it is established.

OPERATION AND MAINTENANCE

A maintenance program shall be established by the landowner/user to maintain capacity and vegetative cover.

1. Protect area of the grade stabilization structure from overgrazing.
2. Fertilize to maintain a vigorous vegetative cover in protected area. Caution shall be used with fertilization to maintain water quality.

3. Mow, spray or chop out undesirable vegetation periodically to prevent growth of large woody-stemmed weeds, water plants such as cattails or trees (such as willows) from embankment and spillway areas.

4. Promptly repair eroded areas.

5. Promptly remove any burrowing rodents that may invade area of embankment.

6. Re-establish vegetative cover immediately where scour erosion has removed established seeding.

7. Keep open all spillways and remove trash that may accumulate around entrance.

8. Periodically inspect area for any new maintenance needs and if any are observed take immediate action to protect from further damage or deterioration.

REFERENCES

National Engineering Field Handbook, Part 650
NRCS, Conservation Practice Standards
Code 342, Critical Area Planting
Code 378, Pond
Code 402, Dam, Floodwater Retarding
Code 638, Water and Sediment Control Basin
Code 412, Grassed Waterway
NRCS, Technical Release No. 55, Urban Hydrology for Small Watersheds June 1986
NRCS, Technical Release No. 60, Earth Dams and Reservoirs Revised Oct. 1985

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

Grassed Waterway

(Acre)

Code 412

DEFINITION

A natural or constructed channel that is shaped or graded to required dimensions and established with suitable vegetation.

PURPOSES

This practice may be applied as part of a resource management system to support one or more of the following purposes:

- To convey runoff from terraces, diversions, or other water concentrations without causing erosion, flooding or ponding.
- To reduce gully erosion.
- To protect/improve water quality.

CONDITIONS WHERE PRACTICE APPLIES

In areas where added water conveyance capacity and vegetative protection are needed to control erosion resulting from concentrated runoff and where such control can be achieved by using this practice alone or combined with other conservation practices.

CRITERIA

General Criteria Applicable to All Purposes
Grassed waterways shall be planned, designed, and constructed to comply with all Federal, State, and local laws and regulations.

The soil, hydrology and vegetative characteristics existing on the site and the contributing watershed shall be documented before construction of the waterway begins.

The effect of any modification to the existing surface and/or subsurface drainage system on other landowners will be evaluated in the design. Surface and subsurface drainage that affects upstream or downstream landowners shall have written permission.

Capacity. The minimum capacity shall be that required to confine the peak runoff expected from a storm of 10-year frequency, 24-hour duration obtained by using the procedure in the NRCS Engineering Field Handbook (EFH) Part 650, Chapter 2.

When the waterway grade is less than 1 percent, out-of bank flow may be permitted if such flow will not cause excessive erosion. The minimum capacity in such cases shall be that required to carry within the channel the discharge as determined by using the “B” drainage curve.

Velocity. Design velocities shall not exceed those obtained by using the procedures, “n” values, and recommendations in the NRCS Engineering Field Handbook (EFH) Part 650, Chapter 7, or Agricultural Research Service (ARS) Agricultural Handbook 667, Stability Design of Grass-lined Open Channels. Velocities that are less than 1.5 feet per second shall require special considerations in the O & M section.

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

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Width. The bottom width of trapezoidal waterways shall not exceed 50 feet unless multiple or divided waterways or other means are provided to control meandering of low flows.

Side Slopes. Side slopes shall not be steeper than a ratio of two horizontal to one vertical. They shall be designed to accommodate the equipment used for normal farming operations.

Crossings. Provide livestock and vehicular crossings as necessary to prevent damage to the waterway and its vegetation.

Depth. The minimum design depth of a waterway that receives water from terraces, diversions, or other tributary channels shall be that required to keep the design water surface elevation at, or below the design water surface elevation in the terrace, diversion, or other tributary channel at their junction when both are flowing at design depth.

Drainage. Designs for sites having prolonged flows, a high water table, or seepage problems shall include Subsurface Drains (NRCS Practice Code 606), Underground Outlets (NRCS Practice Code 620), Stone Center Waterways (EFH Chapter 7) or other suitable measures to avoid saturated conditions.

Outlet. All grassed waterways shall have a stable outlet with adequate capacity to prevent ponding or flooding damages.

Vegetative Establishment. Whenever possible, excess water shall be directed away from the waterway until vegetation is established. Any protective works shall be removed and the disturbed areas within the waterway cross section seeded to permanent grass after the vegetation in the waterway is established.

Apply lime as needed to adjust pH to at least 6.5.

Fertilize according to soil tests or at a minimum rate of 500 lbs. of 12-12-12 fertilizer, or its equivalent, per acre as soon as the waterway has been constructed within the seeding periods.

Seed with one of the following mixes.

Note: Switchgrass / Redtop mix should be seeded only in the spring and only on waterways with drainage areas of 10 acres or less.

Mixes	lbs. of PLS*/acre	Comments
Tall Fescue	35	Fits most situations
Creeping Red Fescue Kentucky Bluegrass	12 10	Shady sites, low velocity sites
Kentucky Bluegrass	45	Low velocity sites
Orchardgrass Perennial Ryegrass	10 8	PRG** for quick establishment, Orchardgrass may take two years to establish.
Orchardgrass Redtop	8 3	Redtop for quick establishment. Best seeded in the spring
Switchgrass Redtop	8 1.5	Seed before June 30. 10 acre maximum watershed
Redtop	8	Quick establishment, low fertility sites.
Orchardgrass Timothy Perennial Ryegrass	6 3 4	PRG** for rapid growth. Best seeded in the fall.
Timothy Perennial Ryegrass Tall Fescue	4 8 6	Best seeded in the fall

The following species may be added for additional wildlife value.

Partridge pea	2 lb./ac.	
Annual Lespedeza	2 lb./ac.	South of I-70
Ladino Clover	0.25 lb./ac.	
Timothy	1 lb./ac.	

*Pure Live Seed **Perennial Rye Grass

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Work the fertilizer and lime into the soil to a depth of 2 to 3 inches with a harrow or disk. Prepare a firm seedbed with a cultipacker or cultipacker type seeder.

Seed during the periods of March 1 to May 10 or August 1 to September 30.

Erosion Control Blanket

An erosion control blanket (ECB) shall be installed on all grassed waterway sections where either of the following exists:

1. The velocity at D retardance is 3.0 feet per second (fps) or greater.

2. Earthfill is used to fill in an eroded area.

The blanket shall be a minimum of 1-ply netting sewn to a straw, excelsior or other accepted mulch material. Severe conditions, such as high velocities coupled with greater depth and/or low likelihood of rapid vegetative establishment will require a heavier ECB. The blanket shall cover the waterway to at least half of the design depth. Installation shall be according to the manufacturer's recommendations.

After temporary seeding only, if the waterway is stable and needs no additional earthwork and the temporary seeding is adequate and the waterway can be seeded with a no-till drill then the erosion control blanket requirement may be waived.

Temporary Seeding:

Waterways constructed between May 10th and August 1st shall be seeded with one of the following species :

Oats @ 2 bushel (64lb.) per acre PLS

Japanese or Pearl Millet @ 30 lb. per acre PLS

Sorghum – Sudan Grass @ 20 lb. per acre PLS

CONSIDERATIONS

Generally, the design velocity for capacity should be based on "C" retardance and the stability should be based on "D" retardance. For sites where Switchgrass / Redtop mixtures are desirable, "B" and "D" retardance should be used.

Special attention should be given to maintaining and improving visual resources and habitat for wildlife where applicable.

The soil loss from the watershed draining into the waterway should be evaluated when the sedimentation from upland erosion on land not controlled by the landowner/user will impair the proper functioning of the waterway.

The waterway should not be constructed until a consideration of upstream erosion control is in place or appropriate land use and/or management changes, have been made to reduce the erosion to an acceptable level.

If possible, consider constructing all waterways with 1 foot of depth as a minimum.

Reducing the amount of trickle flow will enhance vegetative establishment and improve the stability of the waterway. Surface water inlets at the upper reaches of waterway systems may be used to accomplish this. Design drainage according to the "CSM" method in the Engineering Field Handbook Chapter 7.

Water-tolerant vegetation may be an alternative on some wet sites. Contact the NRCS State Forester/Botanist for assistance in selecting appropriate species.

To reduce the risk of vegetative failure, consider using mulch or erosion control blankets on all waterways with velocities greater than 1.5 fps to protect the soil until vegetation is established. Refer to FOTG Standard 484, Mulching, for guidance on materials, quantities and techniques for mulching and erosion control blankets.

Consider increasing the seeding rates by at least 50% on sites considered to be at high risk due to soil type, velocity or other conditions.

An application of 150 lbs. of actual N per acre should be applied to waterways with high design velocity and low in organic matter and fertility, 6 to 8 weeks after seeding. Nitrogen should only be applied to grass during periods of active growth.

Use irrigation in dry regions or supplemental irrigation as necessary to promote germination and vegetation establishment.

Establish filter strips on each side of the waterway to improve water quality since any chemicals applied to the waterway in the course of treatment of adjacent cropland may move directly into the surface waters in the case where there is a runoff even shortly after spraying.

Add width of appropriate vegetation to the sides of the waterway for wildlife habitat.

PLANS AND SPECIFICATIONS

Plans and specifications for grassed waterways shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose(s).

OPERATION AND MAINTENANCE

An operation and maintenance plan shall be provided to and reviewed with the landowner. The plan shall include the following items and others as appropriate.

A maintenance program shall be established to maintain waterway capacity, vegetative cover, and outlet stability. Vegetation damaged by machinery, herbicides, or erosion must be repaired promptly.

Seeding shall be protected from concentrated flow and grazing until vegetation is established.

Grazing shall not be permitted in the grassed waterway unless a controlled grazing system is being implemented. Grazing will be permitted under a controlled grazing system only when soil moisture conditions support livestock traffic without excessive compaction. Warm season grasses should not be grazed closer than 10 inches and cool season grasses should not be grazed closer than 6 inches.

Inspect grassed waterways regularly, especially following heavy rains. Damaged areas should be filled, compacted, and seeded immediately. Remove sediment deposits to maintain capacity.

Landowners should be advised to avoid areas where forbs have been established when applying herbicides. Avoid using waterways as turn-rows during tillage and cultivation operations. Mowing may be appropriate to enhance wildlife values, but must be conducted at a time to avoid peak nesting seasons and reduced winter cover.

Mow or periodically graze vegetation to maintain a healthy, vigorous sod and to maintain capacity and reduce sediment deposition. Time the first mowing after ground nesting birds have hatched (about July 15).

Control noxious weeds.

Do not use as a field road. Avoid crossing with heavy equipment when wet.

Fertilize waterways according to soil tests (not to exceed 500 lbs./acre of 12-12-12, or equivalent) the first spring or fall after seeding and thereafter as necessary to maintain a vigorous stand of grass. Caution should be used during fertilization to maintain water quality.

Repair all broken subsurface drain lines adjacent to or in the waterway.

Re-establish vegetative cover immediately where scour erosion has removed established seeding.

Maintain effective erosion control of the contributing watershed to prevent siltation in the waterway and the resulting loss of capacity.

Velocities that are less than 1.5 feet per second require special attention. The waterway shall be mowed to maintain a maximum grass height of 6 inches. Sediment deposits shall be removed as quickly as possible to maintain the capacity and integrity of the waterway.

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REFERENCES

NRCS Engineering Field Handbook Part 650, Chapter 2. Estimating Runoff and Peak Discharges, 1990

NRCS Engineering Field Handbook Part 650, Chapter 7. Grassed Waterways, 1986

Agricultural Research Service, Agricultural Handbook 667, Stability Design of Grass-lined Open Channels.

Minnesota NRCS Field Office Technical Guide, Practice Standard, Grassed Waterway Code 412.

Missouri NRCS Field Office Technical Guide, Practice Standard, Grassed Waterway Code 412.

Indiana NRCS Field Office Technical Guide, Practice Standard, Filter Strips Code 393.

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

Lined Waterway or Outlet

(Feet)

Code 468

DEFINITION

A waterway or outlet having an erosion-resistant lining of concrete, stone, synthetic turf, reinforcement fabrics, or other permanent material.

PURPOSES

This practice may be applied as part of a resource management system to support one or more of the following purposes:

- Provide for safe conveyance of runoff from conservation structures or other water concentrations without causing erosion or flooding
- Stabilize existing and prevent future gully erosion
- Protect and improve water quality.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies if the following or similar conditions exist:

1. Concentrated runoff is of such that a lining is needed to control erosion.
2. Steep grades, wetness, prolonged base flow, seepage, or piping would cause erosion.
3. The location is of such that use by people or animals preclude use of vegetated waterways or outlets.
4. Limited space is available for design width which requires higher velocities and lining.
5. Soils are highly erosive or other soil or climatic conditions preclude using vegetation.

This practice is not applicable to watercourses where construction of a waterway would destroy woody wildlife cover and the present watercourse is capable of handling the concentrated runoff without serious erosion. Such situations are usually recognized by a meandering condition, steep side slopes that are stabilized by woody plants or herbaceous vegetation, and the watercourse is without rapidly advancing overfalls.

CRITERIA

The planning, installation and maintenance of the lined waterway or outlet shall comply with all fedral, state and local laws, rules and regulations.

Capacity. The maximum capacity of the waterway flowing at designed depth shall not exceed 200 ft^3/s . The minimum capacity shall be adequate to carry the peak rate of runoff from a 10-year-frequency storm. Velocity shall be computed by using Manning's Formula with a coefficient of roughness "n" as follows:

Lining	"n" Value
Concrete	
Trowel finish	0.012 to 0.013
Float finish	0.013 to 0.017
Gunite	0.016 to 0.022
Flagstone	0.020 to 0.025
Riprap	Determine from figure 1.

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

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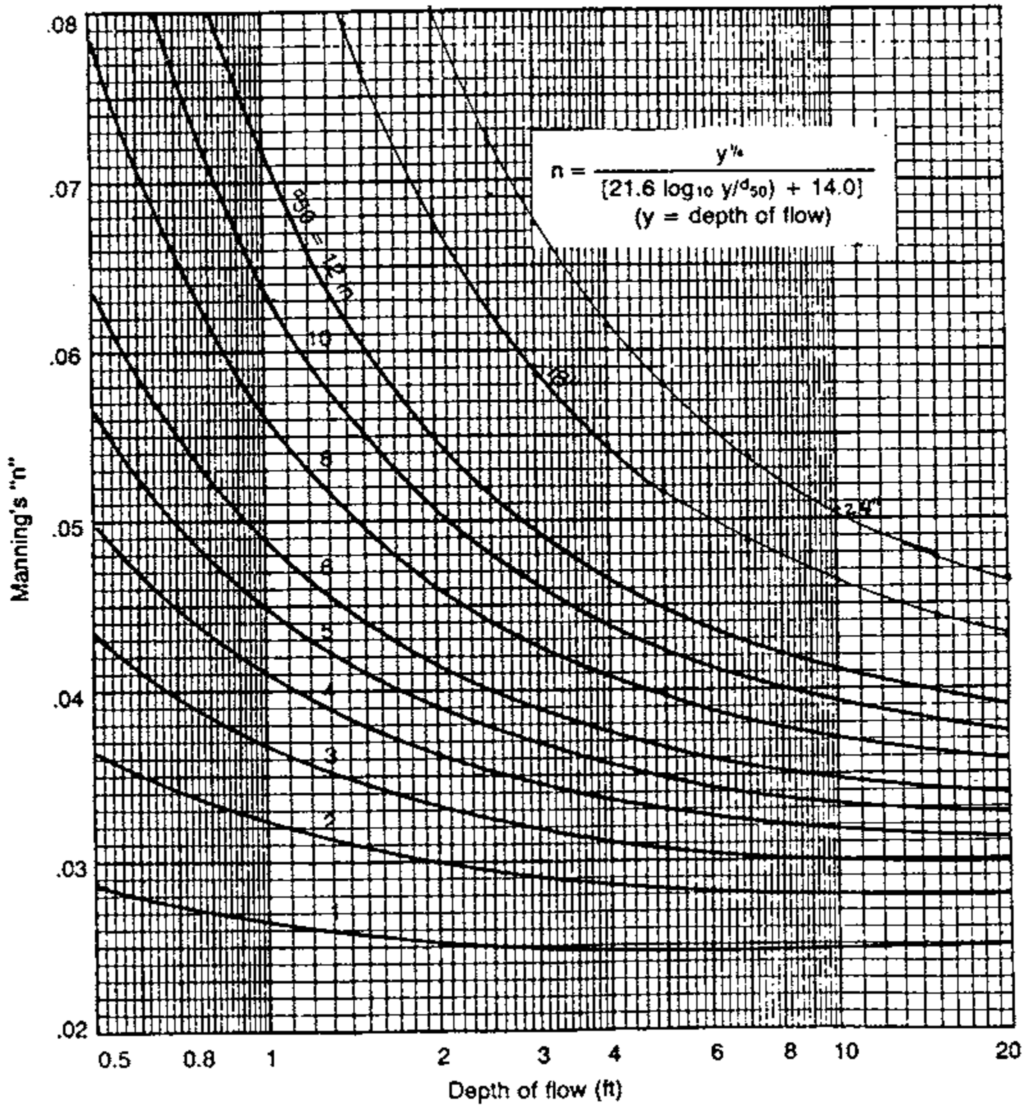

Figure 1. Values of n for riprap-lined channels, d_{50} size vs depth of flow.

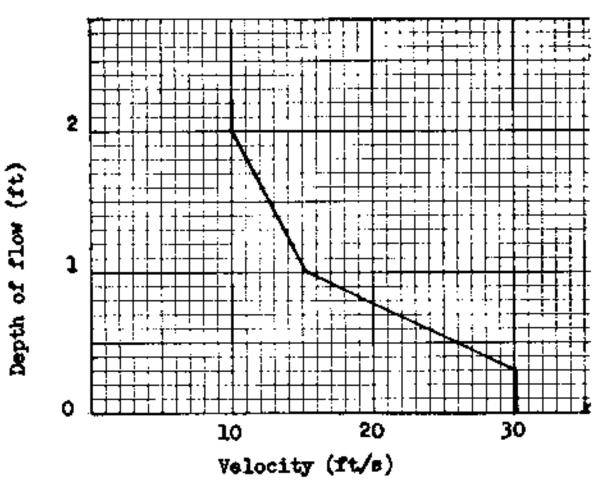

Figure 2. Maximum velocity vs depth of flow for concrete channels.

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Velocity. Maximum design velocity for concrete channels shall be as shown in figure 2. Maximum design velocities for riprap sections shall be less than velocities listed below:

D50 Rock Size	Allowable Velocity
inches	feet per second
4	5.8
5	6.4
6	6.9
7	7.4
8	7.9
9	8.4
10	8.8
11	9.2
12	9.6

Except for short transition sections, flow in the range of 0.7 to 1.3 of the critical slope must be avoided unless the channel is straight. Velocities exceeding critical shall be restricted to straight reaches.

Waterways or outlets with velocities exceeding critical shall discharge into an energy dissipator to reduce velocity to less than critical.

Cross section. The cross section shall be triangular, parabolic, or trapezoidal. Cross sections made of monolithic concrete may be rectangular.

Freeboard. The minimum freeboard for lined waterways or outlets shall be 0.25 feet above design high water in areas where erosion-resistant vegetation cannot be grown adjacent to the paved side slopes. No freeboard is required if vegetation is established and maintained.

Side slope. The steepest permissible side slopes, horizontal to vertical, shall be:

Material	Height of Lining	Side Slope
Hand-placed, formed concrete	1.5 feet or less	vertical
Hand-placed, screened concrete or mortared in-place flagstone	less than 2 feet more than 2 feet	1 to 1 2 to 1
Slip form concrete	less than 3 feet	1 to 1
Rock riprap		2 to 1

Lining thickness. Minimum lining thickness shall be:

Material	Minimum Lining Thickness
Concrete	4 inches (in most problem areas, minimum thickness shall be 5 inches with welded wire fabric reinforcing).
Riprap	Maximum stone size plus thickness of filter or bedding.
Flagstone	4 inches including mortar bed.

Related structures. Side inlets, drop structures, and energy dissipaters shall meet the hydraulic and structural requirements for the site.

Outlets. All lined waterways and outlets shall have a stable outlet with adequate capacity prevent erosion and flooding damages.

Geotextiles. Geotextiles shall be used where appropriate as a separator between rock, flagstone, or concrete linings and soil to prevent migration of soil particles from the subgrade, through the lining material. Geotextiles shall be designed according to AASHTO M288, Section 7.3.

Filters or bedding. Filters or bedding shall be used to prevent piping. Drains shall be used to reduce uplift pressure and to collect water, as required. Filters, bedding, and drains shall be designed according to NRCS standards. Weep holes may be used with drains if needed.

Concrete. Concrete used for lining shall be proportioned so that it is plastic enough for thorough consolidation and stiff enough to stay in place on side slopes. A dense durable product shall be required. Specify a mix that can be certified as suitable to produce a minimum strength of at least 3,000 lb/in^2. Cement used shall be Portland cement, Types I, II or if required, Types IV or V. Aggregate used shall have a maximum size of 1½ inches.

Mortar. Mortar used for mortared in-place flagstone shall consist of a workable mix of cement, sand, and water with a water-cement ratio of not more than 6 gallons of water per bag of cement.

Contraction joints. Contraction joints in concrete linings, if required, shall be formed transversely to a depth of about one-third the thickness of the lining at a uniform spacing in the range of 10 to 15 feet.

Provide for uniform support to the joint to prevent unequal settlement.

Rock riprap or flagstone. Stone used for riprap shall be dense and hard enough to withstand exposure to air, water, freezing, and thawing. Flagstone shall be flat for ease of placement and have the strength to resist exposure and breaking.

CONSIDERATIONS

Consider using a Rock Lined Chute or other practice when overfall is greater than 2 feet (vertically) at a waterway outlet.

Effects on water quantity and quality shall be considered. This practice may have a minor effect on the quantity of surface and ground water. This practice will reduce the erosion in concentrated flow areas resulting in the reduction of sediment and substances delivered to the receiving waters. When used as a stable outlet for another practice, lined waterways may increase the likelihood of dissolved and suspended substances being transported to surface water due to high flow velocities.

Special attention shall be given to maintaining and improving visual resources and habitat for wildlife where applicable. The landowner/user will be advised if wetlands will be affected and USDA/NRCS wetland policy will apply. All work planned shall be in compliance with General Manual Title 450-GM, Part 405, Subpart A, Compliance with Federal, State, and Local Laws and Regulations.

PLANS AND SPECIFICATIONS

Plans and specifications for constructing lined waterways or outlets shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purposes.

OPERATION AND MAINTENANCE

A maintenance program shall be established by the landowner/user to maintain capacity and vegetative cover. Items to consider are:

1. Do not graze lined waterway during establishment and when soil conditions are wet.
2. Protect lined waterway from damage by farm equipment and vehicles. Do not use lined waterway as a roadway and practice care when crossing to prevent tillage marks or wheel tracks.
3. Maintain constructed width by lifting or disengaging tillage equipment properly, and avoid farming operations along lined waterway that would hinder water entry.
4. Observe lining for any deterioration or movement of rock in riprap lined waterways. Perform needed maintenance as soon as possible to eliminate further deterioration or damage.
5. Do not spray with herbicides or cross lined waterways during spray operations unless the equipment is completely shut off.
6. Fertilize vegetated portions of lined waterways the first spring after seeding and thereafter as necessary to maintain a vigorous stand of grass. Caution should be used with fertilization to maintain water quality.
7. Mow vegetated portions of lined waterways regularly to maintain a healthy, vigorous sod. Time the first mowing after ground-nesting birds have hatched (about August 1). Remove excess top growth. Do not burn or overgraze.
8. Repair all broken subsurface drain lines adjacent to or in the waterway.
9. Re-establish vegetative cover immediately where scour erosion has removed established seeding or vegetated portion of lined waterway.
10. Maintain effective erosion control of the contributing watershed to prevent siltation and the resulting loss of capacity.

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

Mulching

(Acre)

Code 484

DEFINITION

Applying plant residues or other suitable materials not produced on the site to the soil surface.

PURPOSES

To conserve moisture, prevent surface compaction or crusting; reduce runoff and erosion; control weeds; and help establish new plant cover.

CONDITIONS WHERE PRACTICE APPLIES

On soils subject to erosion on which low-residue-producing crops, such as grapes and small fruits are grown; on critical areas; and on soils that have a low infiltration rate.

CRITERIA

General criteria applicable to all purposes

This standard shall be used in compliance with all federal, state and local laws and regulations.

Additional criteria to conserve moisture; prevent surface compacting or crusting; reduce runoff and erosion; and help establish plant cover:

When possible, concentrated flow of surface runoff water shall be diverted from above the area to be mulched.

All areas to be mulched shall be free of rills and gullies.

Immediately after seeding and fertilizing (unless a dormant seeding is to be made), uniformly apply 1 1/2 to 2 tons per acre of straw that is clean and free of noxious weed seeds. At the appropriate application rate, some soil can be seen.

Straw mulch shall be anchored using one of the following methods:

- Crimp or punch mulch into the ground to an approximate depth of 2 inches.
- Apply emulsified asphalt (or other suitable tackifier material) to the mulch according to manufacturer's recommendations. Emulsified asphalt shall not be used when air temperatures are below 32°F. Follow manufacturer's recommendations on mixing and temperature control.
- Apply mulch netting of lightweight paper, jute, cotton or plastic and fasten it to soil according to manufacturer's recommendation.

Alternative mulch materials may be used in lieu of straw mulch at rates and requirements listed in Table 1.

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

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Table 1. Alternative mulch materials

Material	Quality	Rate	Remarks
Hay	Air-dried; free of mold; Free of noxious weeds	2 tons per acre	Anchor like straw
Wood excelsior	Green or air dried burred wood fiber.	2 tons per acre	Anchor with tackifier or netting
Wood fiber cellulose	Partially digested wood fiber; usually with green dye and a dispersing agent.	2,000 lb per acre	Apply with hydroseeder
Jute mat	Undyed, unbleached plain weave; warp 78 ends/yd; weft 41 ends/yd; 60-90 lb rolls.	48 in x 50 yd or 48 in x 75 yd.	Secure as per manufacturer's specification
Excelsior wood fiber mats	Interlocking web of excelsior fibers with photodegradable plastic netting.	48- x 100- inch 2-sided plastic or 48- x 180-inch 1-sided plastic.	Secure as per manufacturer's specification
Straw, coconut or combined mats	Photodegradable plastic net on one or two sides.	6.5 x 83.5 ft, 81 rolls per acre.	Secure as per manufacturer's specification

Additional criteria to conserve moisture and control weeds:

Orchards

Approximately four tons per acre of dry matter shall be applied around the trees.

Mulch shall be extended out to or beyond the tree's dripline, and shall be thick enough to smother any grass and weeds beneath the tree.

Mulch shall be kept back two feet from trunk of tree to discourage mouse damage.

Vineyards and Berries

After vineyard is established, apply mulch six (6) or more inches deep to replace cultivation and conserve moisture.

Row Crops

Weeds shall be controlled by use of cultivation or chemicals before applying mulch.

Apply approximately two (2) tons per acre of clean, dry straw that is free of noxious weeds.

Mulch shall be applied, as soon as possible, after weed control and before crop height prevents spreading of mulch.

After application of mulch, do not cultivate. Control weeds, as needed, by use of chemicals.

CONSIDERATIONS

- Mulching can reduce erosion and the movement of sediment and sediment-attached substances carried by runoff.
- Consider fire potential.

- In areas of high erosion potential, such as waterways with high velocities (design velocity at > 3 feet per second), an erosion control blanket should be installed according to manufacturer's recommendations in lieu of loose mulch.

PLANS AND SPECIFICATIONS

Plans and specifications will be developed for specific field sites in accordance with this practice standard.

OPERATION AND MAINTENANCE

An operation and maintenance plan will be developed in keeping with this practice standard.

REFERENCES

U.S. Department of Agriculture, Natural Resources Conservation Service, National Agronomy Manual, Part 506, *Plant Attributes*, 1999.

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

Pond

(Number)

Code 378

DEFINITION

A water impoundment made by constructing a dam or an embankment or by excavating a pit or dugout.

In this standard, ponds constructed by the first method are referred to as embankment ponds, and those constructed by the second method are referred to as excavated ponds. Ponds constructed by both the excavation and the embankment methods are classified as embankment ponds if the depth of water impounded against the embankment at spillway elevation is 3 feet or more.

PURPOSES

To provide water for livestock, fish and wildlife, recreation, fire control, and other related uses, and to maintain or improve water quality.

CONDITIONS WHERE PRACTICE APPLIES

This standard establishes the minimum acceptable criteria for the design and construction of ponds if:

1. Failure of the dam will not result in loss of life; or damage to homes, commercial or industrial buildings, main highways, or railroads; or in interruption of the use or service of public utilities.

2. The product of the storage times the effective height of the dam is less than 3,000. Storage is the volume, in acre-feet, in the reservoir below the elevation of the crest of the auxiliary spillway or the top of fill if there is no auxiliary spillway. The effective height of the dam is the difference in elevation, in feet, between the auxiliary spillway crest and the lowest point in the cross section taken along the centerline of the dam. If there is no auxiliary spillway, the top of the dam is the upper limit.

3. The effective height of the dam is 35 feet or less, and the dam is hazard class (a). See National Engineering Manual 520.23 (b) for documentation of hazard classification.

Site conditions. Site conditions shall be such that runoff from the design storm can be safely passed through (1) a natural or constructed auxiliary spillway, (2) a combination of a principal spillway and an auxiliary spillway, or (3) a principal spillway.

Drainage area. The drainage area above the pond must be protected against erosion to the extent that expected sedimentation will not shorten the planned effective life of the structure.

The drainage area shall be large enough so that surface runoff and ground water flow will maintain an adequate supply of water in the pond. The ratio of pond area to drainage area should fall within the following guidelines:

(a) For slowly permeable soils (Hydrologic Group C & D soils) having slopes greater than seven (7) percent – not less than 1:4 or more than 1:20.

(b) For moderately permeable soils (Hydrologic Group B & C soils) and slowly

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permeable soils with less than seven (7) percent slopes – not less than 1:6 or more than 1:25.

(c) For permeable soils (Hydrologic Group A soils) – not less than 1:10 or more than 1:30.

The water quality shall be suitable for its intended use. Runoff water from barnyards, feedlots, septic tanks, barn drains, or other sources of contamination shall be diverted so as not to flow into ponds to be used for livestock water supply, fish and wildlife, or recreation.

Reservoir area. The topography and soils of the site shall permit storage of water at a depth and volume that ensure a dependable supply, considering beneficial use, sedimentation, season of use, and evaporation and seepage losses. If surface runoff is the primary source of water for a pond, the soils shall be impervious enough to prevent excessive seepage losses or shall be of a type that sealing is practicable.

CRITERIA

General Criteria for Embankment and Excavated Ponds

The design, construction and operation of the pond shall comply with all federal, state and local laws, rules and regulations.

Minimum depth shall be 8 feet over at least 25 percent of pond or pit area at permanent water level, or where underlying rock prevents excavation to that depth, a minimum of 6 feet over at least 50 percent of the area.

When the primary purpose is for fish production, at least 75 percent of the shoreline shall be steepened to a slope of three horizontal to one vertical to a depth of 3 feet below permanent pool level. Ponds or pits primarily for fish production shall have a minimum surface area of not less than 0.25 acre when stocked with a single species or a minimum surface area of 0.5 acre when stocked with two or more species.

All others shall have a surface area adequate for the intended purpose, with a minimum surface area of 0.15 acre for excavated ponds and 0.25 acre for embankment ponds.

Vegetation. A protective cover of vegetation shall be established on all exposed surfaces of the embankment, spillway, borrow and spoil areas and to a minimum of 50 feet on all sides of pond and 100 feet upstream of the pool area. Open areas to be vegetated will be limed, fertilized, seeded and mulched according to the construction specification. No woody vegetation shall be planted on or within 25 feet of the embankment or spillway.

Fencing. When embankment ponds are used for livestock water, the entire fill, spillways and pond area shall be fenced to exclude livestock. Fencing shall be a minimum of 30 feet from all sides of the pond and a minimum of 50 feet upstream of the pool area. Flash grazing is allowed only with a grazing plan. Watering facilities for stock shall be provided outside the fenced area. All fencing shall be in accordance with the Field Office Technical Guide (FOTG) Standard (382) Fence.

Additional Criteria for Embankment Ponds

Foundation and soil investigation. The foundation on which a dam is to be placed shall have sufficient bearing strength to support the dam without excessive consolidation. Investigation shall be made of the fill site, pool area, and borrow areas to determine if the requirements listed for Foundation Cutoff can be met. The investigation shall be in sufficient detail to determine that adequate borrow is available, that the auxiliary spillway can be excavated as planned, that the mechanical spillway foundation is suitable, and the pond can maintain normal pool level. A more extensive investigation must be done in karst areas. Soil materials shall be classified using the Unified Soil Classification System.

Foundation cutoff. A cutoff of relatively impervious material shall be provided under the dam. The cutoff shall be located at or upstream from the centerline of the dam. It shall extend up the abutments as required and be deep enough (2 foot minimum) to extend into a relatively impervious layer or provide for a stable dam when combined with seepage control. Where the possibility of subsurface drains exist, the cutoff shall be deep enough to intercept them. The cut off trench shall have an 8-foot minimum bottom width to accommodate the equipment used for excavation, backfill, and compaction operations. Side slopes shall not be steeper than one horizontal to one vertical.

The most impervious material available shall be used to backfill the cutoff trench and to construct the core of the dam.

Seepage control. Seepage control is to be included if (1) pervious layers are not intercepted by the cutoff, (2) seepage may create swamping downstream, (3) such control is needed to insure a stable embankment, or (4) special problems require drainage for a stable dam. Seepage may be controlled by (1) foundation, abutment, or embankment drains; (2) reservoir blanketing or sealing; or (3) a combination of these measures.

Earth embankment. The minimum top width for a dam is shown in Table 1. If the embankment top is to be used as a public road, the minimum width shall be 16 feet for one-way traffic and 26 feet for two-way traffic. Guardrails or other safety measures shall be used where necessary and shall meet the requirements of the responsible road authority.

Table 1. Minimum top width for dams.

Total Height of Embankment (feet)	Top Width (feet)
<10	6
10 to <15	8
15 to <20	10
20 to <25	12
25 to <35	14

The combined upstream and downstream side slopes of the settled embankments shall not be less than five horizontal to one vertical with the upstream slope never steeper than two and one-half horizontal to one vertical, and the downstream slope never steeper than two horizontal to one vertical. Slopes shall be designed to be stable, even if flatter side slopes and/or berms are required. The downstream slope shall be two and one-half horizontal to one vertical or flatter, if the dam is to be mowed.

If needed to protect the slopes of the dam, special measures, such as berms, rock riprap, sand-gravel, soil cement, or special vegetation, shall be provided (NRCS Technical Releases 56 and 69).

The minimum elevation of the top of the settled embankment shall be 1 foot above the water surface in the reservoir with the auxiliary spillway flowing at design depth. The minimum difference in elevation between the crest of the auxiliary spillway and the settled top of the dam shall be 2 feet for all dams having more than a 20-acre drainage area or more than 20 feet in effective height.

The design height of the dam shall be increased by the amount needed to insure that after settlement the height of the dam equals or exceeds the design height. This increase shall not be less than 5 percent, except where detailed soil testing and laboratory analyses show a lesser amount is adequate.

Principal spillway. A pipe conduit, with needed appurtenances, shall be placed under or through the dam except:

1) Where rock, concrete, or other type of mechanical spillways are used;

2) For drainage areas less than 10 acres not fed by springs or seep;

3) Where the rate and duration of flow can be safely handled by a vegetated or earth spillway.

When design discharge of the principal spillway is considered in calculating peak outflow through the auxiliary spillway, the crest elevation of the inlet shall be such that the full flow will be generated in the conduit before there is discharge through the auxiliary spillway. The inlets and outlets shall be designed to function satisfactorily for the full range of flow and hydraulic head anticipated.

The capacity of the pipe conduit shall be adequate to discharge long-duration, continuous, or frequent flows without flow through the auxiliary spillways. The minimum diameter of pipe, minimum frequency design and detention storage shall be determined from Table 2 for the principal spillway.

Pipe conduits under or through the dam shall meet the following requirements. The pipe shall be capable of withstanding external loading without yielding, buckling, or cracking. Flexible pipe strength shall not be less than that necessary to support the design load with a maximum of 5 percent deflection. Pipe strength shall not be less than that of the grades indicated in Table 3 or 4 for plastic pipe and in Table 5 for corrugated aluminum, aluminized corrugated steel and galvanized steel pipe. The inlets and outlets shall be structurally sound and made of materials compatible with those of the pipe. All pipe joints shall be made watertight by the use of coupling, gaskets, caulking, or by welding.

For dams 20 feet or less in effective height, acceptable pipe materials are cast or ductile iron, steel, corrugated steel or aluminum, concrete, plastic, and cast-in-place reinforced concrete. Concrete pipe shall be laid in a concrete bedding. Plastic pipe that will be exposed to direct sunlight shall be made of ultraviolet-resistant materials and protected by coating or shielding, or provisions for replacement should be made as necessary. Connections of plastic pipe to less flexible pipe or structure must be designed to avoid stress concentrations that could rupture the plastic.

For dams more than 20 feet in effective height, conduits shall be plastic, reinforced concrete, cast in-place reinforced concrete, ductile iron, corrugated steel or aluminum, or welded steel pipe. Pipe shall be watertight. The joints between sections of pipe shall be designed to remain watertight after joint elongation caused by foundation consolidation. Concrete pipe shall have concrete bedding or a concrete cradle. Cantilever outlet sections, if used, shall be designed to withstand the cantilever load. Pipe supports shall be provided when needed. Other suitable devices such as a Saint Anthony Fall stilling basin (S.A.F.), stilling basin, or an impact basin may be used to provide a safe outlet. Protective coatings of fiber bonded, asphalt coated, or vinyl coating on galvanized corrugated metal pipe, or coal tar enamel on welded steel pipe shall be provided in areas that have a history of pipe corrosion, or where the saturated soil resistivity is less than 4,000 ohms-cm, or where soil pH is lower than 5.

Table 2

Minimum requirements for structures located in predominantly rural or agricultural areas and incorporating water detention and/or retention storage in their design where (1) the hazard class of the structure is “a”, (2) the product of the storage[1] times the effective height of dam[2] is less than 3000, and (3) the effective height of dam[2] is 35 feet or less.

<table>
<tr><th>Drainage Area</th><th>Effective Height of Dam 2/</th><th>Storage 1/</th><th>Principal Spillway (24-hour Storm AMCII)</th><th>Auxiliary Spillway (24 hour Storm) 4/</th><th>Top of Settled Fill</th></tr>
<tr><td>10 acres or less without Conduit 3/</td><td>Less than 20 feet</td><td rowspan="4">Less than 50 acre feet</td><td>See Note 3</td><td rowspan="2">Route Q_{10}
6/</td><td rowspan="5">Minimum of 1 foot freeboard above the Hp value for the auxiliary spillway, but at least 2 feet above the crest of the auxiliary spillway for all dams having more than 20 acres drainage area or more than 20 feet in effective height. 9/</td></tr>
<tr><td rowspan="2">20 acres
or less
5/</td><td>Less than 20 feet</td><td>1.0” Detention Storage (minimum) or Route Q_2. 8/</td></tr>
<tr><td>20 feet or more</td><td rowspan="2">1.5” Detention Storage 7/
minimum or
Q Route 5 yr. freq. 8/</td><td rowspan="2">Route Q_{25}
6/</td></tr>
<tr><td>Over 20 acres
5/</td><td></td></tr>
<tr><td>ALL OTHERS
5/</td><td></td><td></td><td>2.0” Detention Storage 7/ (minimum) or Q Route 10 yr. freq. 8/</td><td>Route Q_{50}
6/</td></tr>
</table>

1/ Storage is defined in “Conditions Where Practice Applies”.

2/ Effective height of dam is defined in “Conditions Where Practice Applies”.

3/ Where the pond is spring fed or other source of steady base flow, a pipe shall be installed with a capacity at least equal to the maximum spring or base flow.

4/ Auxiliary spillway crest shall be set above the storage requirements of the principal spillway, but not lower than the elevation at which the principal spillway conduit flows full. The crest of the auxiliary spillway shall be at least 0.5 feet above the crest of the principal spillway for less than 20 acres drainage area and at least 1.0 feet above the crest of the principal spillway for greater than 20 acres drainage area.

5/ A principal spillway conduit is required. Minimum pipe diameter shall be 4 inches smooth pipe or 6 inches corrugated metal pipe.

6/ Flow through the principal spillway shall not be included if the pipe diameter is less than 10 inches.

7/ Minimum pipe diameter shall be 10 inches.

8/ Storage may be determined by short cut methods on Engineering Field Handbook pages 11.55a, 11.55b, and 11.55c or Hydro-yardage computer program.

9/ Where IDNR approval is required, additional freeboard may be required. Consult the NRCS State Conservation Engineer for instructions.

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Specifications in Tables 3, 4, and 5 are to be followed for polyvinyl chloride (PVC), high density polyethylene (HDPE), steel, and aluminum pipe.

Cathodic protection is to be provided for coated welded steel and galvanized corrugated metal pipe where soil and resistivity studies indicate that the pipe needs a protective coating, and where the need and importance of the structure warrant additional protection and longevity. If cathodic protection is not provided for in the original design and installation, electrical continuity in the form of join-bridging straps should be considered on pipe that have protective coatings. Cathodic protection shall be added later if monitoring indicates the need.

National NRCS practice standard 430-FF Irrigation Water Conveyance, Pipeline, Steel provides criteria for cathodic protection of welded steel pipe.

When concrete pipe is used for the conduit, concrete shall also be placed around the outside of the riser enclosing the first joint of the conduit.

Risers or inlets for pipe conduits shall be of the same material as the conduit, or of comparable life materials such as reinforced concrete, concrete blocks, concrete culvert pipe, welded steel pipe or corrugated metal pipe. Hooded or canopy inlet may be used in lieu of a riser.

Risers shall have a cross-sectional area at least 1.5 times that of the principal spillway conduit which outlets from it, but not less than 18 inches diameter.

Risers shall have a height adequate to ensure full pipe flow in the barrel. All pipe risers shall have an extra foot of length below the invert of the conduit encased in concrete to the invert of the conduit.

Closed conduit spillways designed for pressure flow must have adequate anti-vortex devices.

To prevent clogging of the conduit, an appropriate trash guard shall be installed at the inlet or riser.

The riser or inlet will be protected from ice and floating debris by a semi-circular berm not less than 4 feet from the riser. No berm is necessary when a hooded or canopy inlet is used but the invert of the inlet shall project one (1) foot vertically above the fill slope.

Table 3. Acceptable PVC pipe for use in earth dams. [1]

Nominal pipe size (inches)	Schedule for standard dimension ratio (SDR)	Maximum depth of fill over pipe (feet)
6 or smaller	SDR 26	10
	Schedule 40	15
	Schedule 80	20
8, 10, 12	SDR 26	10
	Schedule 40	10
	Schedule 80	15

1/ Polyvinyl chloride pipe, PVC 1120 or PVC 1220, that conform to ASTM-D-1785 or ASTM-D-2241.

Table 4. Acceptable HDPE pipe for use in earth dams. [1]

Pipe Values	Maximum height of fill over the top of pipe[2] (feet)
SDR 21-32.5 PS 34-50	10
SDR 17 PS 100	11.5

1/ High density polyethylene pipe, ASTM-D3350 flexural modulus cell class 4 or greater, conforming to ASTM F714 for smooth wall HDPE pipe or AASHTO M-252 or M-294 for double wall HDPE pipe. These materials will typically have standard dimension ratio (SDR) values ranging from 32.5 to 21 or pipe stiffness (PS) values ranging from 34 to 100 psi respectively.

2/ The maximum height of fill over top of the pipe. This is based on 0 degree bedding (line support at the invert only). Backfill is assumed to be at 85 to 95% of maximum standard proctor density.

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Table 5. Minimum sheet thickness for corrugated steel pipe (2-2/3 in x ½ in corrugations). [1,2]

Diameter of pipe (inches)	Fill height (feet)		
	1 to <15	15 to <20	20 to 25
21 and less	0.064	0.064	0.064
24	0.064	0.064	0.064
30	0.064	0.064	0.079
36	0.079	0.079	0.109
42	0.109	0.109	0.138
48	0.138	0.138	0.138

Minimum sheet thickness (in) of aluminum pipe. [3]

Diameter of pipe (inches)	Fill height (feet)		
	1 to <15	15 to <20	20 to 25
21 and less	0.060	0.060	0.060
24	0.060	0.075	0.105
30	0.075	0.105	0.135
36	0.075	0.105	[4]

1/ Pipe with 6, 8 and 10-inch diameters has 1-1/2 in x ¼ in corrugations.
2/ Conforming to ASTM A760, A762 and A885.

3/ Riveted or helical fabrication, that conforms to ASTM B745 and B790.
4/ Not permitted.

Seepage control along a pipe conduit spillway or pond drain shall be provided in the normal saturation zone. Seepage along pipes extending through the embankment shall be controlled by use of a filter and drainage diaphragm, unless it is determined that antiseep collars will adequately serve the purpose.

The drain is to consist of sand, meeting fine concrete aggregate requirements (at least 15% passing the No. 40 sieve but no more than 10% passing the No. 100 sieve). If unusual soil conditions exist, a special design analysis shall be made.

The drain shall be a minimum of 2 feet thick and extend vertically upward and horizontally at least three times the pipe diameter, and vertically downward at least 18 inches beneath the bedding or cradle. The drain diaphragm shall be located immediately downstream of the cutoff trench, approximately parallel to the centerline of the dam.

The drain shall be outletted at the embankment downstream toe, preferably using a drain backfill envelope continuously along the pipe to where it exits the embankment. Riprap shall be used to cover the drain outlet to protect it from surface erosion.

When anti-seep collars are used in lieu of a drainage diaphragm, they shall have a watertight connection to the pipe. Collar material shall be compatible with pipe materials. Maximum spacing shall be approximately 14 times the minimum projection of the collar measured perpendicular to the pipe, but not more than 25 feet. The first collar shall not be more than 14 feet downstream of the inlet. The antiseep collar(s) shall increase by 15% the seepage path along the pipe.

Where the downstream channel conditions are stable, the pier may be omitted for conduits of 15 inch diameter or less with the outlet invert one (1) to two (2) feet above the stable channel bottom. The outlet section shall be a minimum of 20 feet in length with a four (4) feet to eight (8) feet overhang downstream from the intersection of the flow line of the pipe and the design fill slope.

For conduits larger than 15-inch diameter, conduits with outlets higher than two (2) feet above the grade of the channel bottom or conduits outletting in unstable outlet channels, a cantilever propped outlet or other suitable devices such as a S.A.F. stilling basin, or impact basin will be provided. For cantilevered (propped) outlets, the outlet section of pipe shall be a minimum of 20 feet long, with the prop (or pier) located at or downstream from the intersection of the fill slope and the outlet channel grade. Approximately one-third of the outlet pipe section (minimum of 8 feet) shall be downstream of the pier centerline. A stilling basin shall be excavated and lined with riprap if necessary to prevent erosion at the outlet.

A pipe with a suitable valve shall be provided to drain the pool area if needed for proper pond management. The principal spillway conduit may be used as a pond drain if it is located where it can perform this function. The drain shall be large enough to draw the pond down 8 feet in 2 weeks (approximately 16 GPM or 0.04 cfs. per A.F. of storage).

Supply pipes through the dam to watering troughs and other appurtenances shall have an inside diameter of not less than 1¼ inches.

Auxiliary spillways. An auxiliary spillway must be provided for each dam, unless the principal spillway is large enough to pass the peak discharge from the routed design hydrograph and the trash that comes to it without overtopping the dam. The following are minimum criteria for acceptable use of closed conduit principal spillway without an auxiliary spillway: a conduit with a cross-sectional area of 3 square feet or more, an inlet that will not clog, and an elbow designed to facilitate the passage of trash.

The minimum capacity of a natural or constructed auxiliary spillway shall be that required to pass the peak flow expected from a design storm of the frequency and duration shown in Table 2.

The auxiliary spillway shall safely pass the peak flow, or the storm runoff shall be routed through the reservoir. The routing shall start either with the water surface at the elevation of the crest of the principal spillway or at the water surface after 10 days' drawdown, whichever is higher. The 10-day drawdown shall be computed from the crest of the auxiliary spillway or from the elevation that would be attained if the entire design storm were impounded, whichever is lower. Auxiliary spillways shall provide for passing the design flow at a safe velocity to a point downstream where the dam will not be endangered.

Constructed auxiliary spillways are open channels that usually consist of an inlet channel, a control section, and an exit channel. They shall be trapezoidal and shall be located in undisturbed or compacted earth. The side slope shall be stable for the material in which the spillway is to be constructed, but not steeper than two horizontal to one vertical except when cut in rock. The minimum auxiliary spillway bottom width shall be 10 feet.

The control section shall be level for a minimum distance of 10 feet. The inlet channel shall be at least the same width as the control section and may be curved to fit existing topography. The grade of the exit channel of a constructed auxiliary spillway shall fall within the range established by discharge requirements and permissible velocities. The constructed exit channel shall be straight and uniform to a point downstream of the toe of the dam.

Structural auxiliary spillway. If chutes or drops are used for principal spillways or auxiliary spillways, they shall be designed according to the principles set forth in the Engineering Field Manual for Conservation Practices and the National Engineering Handbook-Section 5, Hydraulics; Section 11, Drop Spillways; and Section 14, Chute Spillways. The minimum capacity of a structural spillway shall be that required to pass the peak flow expected from a design storm of the frequency and duration shown in Table 2.

Additional Criteria for Excavated Ponds

General. This type of reservoir is generally constructed in flat land areas where an embankment pond is not feasible. The water supply is obtained from underground seepage, high water table, springs, subsurface drains or surface runoff. An adequate water supply which will maintain desired water level in pond must be assured.

Outlet. Provisions shall be made for a pipe and auxiliary spillway if necessary (see Table 2). Runoff flow patterns shall be considered when locating the pit and placing the spoil.

Depth. Depth requirements shall be the same as for embankment ponds, except that if the water supply is derived from seeps or spring flows, the pit must have a depth of at least 4 feet over 25 percent of the pit area.

Side slopes. Side slopes of excavated ponds shall be stable and shall not be steeper than the minimum side slopes shown in Table 6.

Table 6. Steepest Allowable Side Slopes

Texture	Horizontal:Vertical
Peat and Muck	1:1
Fine Sand	2.5:1
Coarse Sand and Gravel	2:1
Silt Loam or Loam	2:1
Sandy Loam	2:1
Clay Loam or Silty Clay Loam	1.5:1

Inlet protection. If surface water enters the pond in a natural or excavated channel, the side slope of the pond shall be protected against erosion.

Excavated material. The material excavated from the pond shall be placed so that its weight will not endanger the stability of the pond side slopes and so that it will not be washed back into the pond by rainfall. It shall be disposed of in one of the following ways:

1. Uniformly spread to a height that does not exceed 3 feet with the top graded to a continuous slope away from the pond.
2. Uniformly placed or shaped reasonably well with side slopes assuming a natural angle of repose. The excavated material will be placed at a distance equal to the depth of the pond but not less than 12 feet from the edge of the pond.
3. Shaped to a designed form that blends visually with the landscape.
4. Used for low embankment and leveling.
5. Hauled away.

Safety. Ponds and pits can create a safety hazard. Appropriate safety features and devices shall be installed to protect people and animals from accidents such as falling or drowning, if appropriate.

CONSIDERATIONS

Considerations should be given to the use of construction materials, grading practices, vegetation and other site development elements that minimize visual impacts and maintain or supplement existing landscape uses.

Excess excavated material may be used to construct earth fishing piers into the pond and/or nesting islands.

The visual design of ponds should be carefully considered in areas of high public visibility and those associated with recreation. The underlying criterion for all visual design is appropriateness. The shape and form of ponds, excavated material, and plantings are to relate visually to their surroundings and to their function.

The embankment may be shaped to blend with the natural topography. The edge of the pond may be shaped so that it is generally curvilinear rather than rectangular. Excavated material can be shaped so that the final form is smooth, flowing, and fitting to the adjacent landscape rather than angular geometric mounds. If feasible, islands may be added for visual interest and to attract wildlife.

Consider using a trickle tube to keep auxiliary spillways from eroding from wetness when no principal spillway pipe is installed.

PLANS AND SPECIFICATIONS

Plans and specifications for construction of ponds shall be in keeping with this standard and shall describe the requirements for properly installing the practice to achieve its intended purpose.

OPERATION AND MAINTENANCE

An operation and maintenance plan will be developed for the landowner in keeping with this practice standard. At a minimum, the following items shall be addressed:

1. Remove any woody growth from embankments and spillway areas. Keep grasses mowed for better visual inspection.

2. Remove debris and trash from spillways and outlets immediately. Inspect the outlet regularly, especially after storm events.

3. Control burrowing animals. Repair any holes caused by burrowing animals on or near the embankment.

4. Repair any erosion of the embankment.

5. Inspect the embankment for seepage downstream.

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Indiana NRCS FOTG – October, 2002.

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

Riparian Forest Buffer

(Acres)

Code 391

DEFINITION

An area of predominantly trees and/or shrubs located adjacent to and up-gradient from watercourses or water bodies.

PURPOSES

- Create shade to lower water temperatures to improve habitat for aquatic organisms.
- Provide a source of detritus and large woody debris for aquatic and terrestrial organisms.
- Create wildlife habitat and establish wildlife corridors.
- Reduce excess amounts of sediment, organic material, nutrients and pesticides in surface runoff and reduce excess nutrients and other chemicals in shallow ground water flow.
- Provide a harvestable crop of timber, fiber, forage, fruit, or other crops consistent with other intended purposes.
- Provide protection against scour erosion within the floodplain.
- Restore natural riparian plant communities.
- Moderate winter temperatures to reduce freezing of aquatic over-wintering habitats.
- To increase carbon storage.

CONDITIONS WHERE PRACTICE APPLIES

On areas adjacent to permanent or intermittent streams, lakes, ponds, wetlands and areas with ground water recharge that are capable of supporting woody vegetation.

CRITERIA

General Criteria Applicable to All Purposes

- Plans and application of riparian forest buffer shall comply with all applicable federal, state, and local laws and regulations.
- Dominant vegetation shall consist of existing, planted or seeded trees and shrubs adapted to the site and the intended purpose.
- The species, type of plant material, location, layout and density of the planting shall accomplish the intended purpose and function.
- Native plant species shall be used whenever possible. Known non-native invasive species shall not be used.
- Removal of trees for timber products shall not compromise the intended purpose of the buffer.
- Livestock shall be controlled or excluded as necessary to achieve and maintain the intended purpose.
- Riparian buffers shall be designed to meet the minimum buffer width as designated in Table 1.
- Woody plants shall be established without compromising the integrity of:
  1. Property Lines
  2. Fences
  3. Utilities

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4. Roads
5. Legal Drains
6. Other Easement Areas or Right of Ways

- Where subsurface drains (tile lines) cross through a tree/shrub planting, and where these drains will remain functional, non-perforated tile shall be installed through the planting and extend a minimum of 50 feet on either side of the planting, or trees/shrubs shall not be planted within 50 feet on either side of the perforated tile line.

- **Buffer Configuration**

All buffers shall consist of at least two zones, Zone 1 and Zone 2. In addition, Zone 3 shall be required if needed to control erosion up-gradient of Zone 2.

Zone 1 – Streamside Forest

Shall begin at the normal water line, or at the top upper edge of the active channel or shore, extend a minimum distance of 25 feet measured horizontally on a line perpendicular to the water body. Tree removal is minimized in this zone to allow trees to grow to maturity. Mature trees are needed to lower water temperatures and to provide a source of detritus for fish and other aquatic organisms. Occasional removal of trees for forest products is permitted provided that the intent of the buffer is not compromised. Felling and skidding of trees shall be directed away from the water course or water body. Skidding shall be done in a manner that minimizes soil erosion.

Exception for legal drains (only with written permission): Zone 1 can begin 30 feet from the top of bank to provide an access strip for equipment ingress and egress.

The access strip is allowable if the primary purpose of the buffer is attainable with the presence of the access strip. The access strip shall be maintained in herbaceous plants.

- Written permission shall be obtained for all easements.

Zone 2 – Managed Forest

Shall begin immediately from Zone 1 and extend a minimum distance listed in Table 1. Minimum Zone Widths.

Criteria for Zone 1 applies except that removal of trees for forest products is permitted on a periodic and regular basis provided the intended purpose is not compromised.

Table 1. Minimum Zone Widths (in feet)

Stream Order[1]	Zone 1	Zone 2	Total
1,2	25	25	50
3 and larger	25	75	100
Others[2]	25	25	50

[1] Stream order is a description of a drainage pattern. It is a measure of the position of a stream in the hierarchy of tributaries. First order streams are those which have no tributaries. Stream order increases when 2 streams of equal order join. For example, it takes 2 second order streams joining to make a third order stream.
[2] Includes open ditches and streams that have surface flow for less than 6 months out of the year. Also includes buffers around wetlands, lakes, and ponds.

Zone 3 – Stiff-Stemmed Grasses

Where ephemeral, concentrated flow or sheet and rill erosion is a concern in the area up-gradient of Zone 2, install a vegetated filter strip of grasses and/or forbs. When Zone 3 is used it shall be applied in accordance with FOTG (391) *Filter Strip* with a minimum width of 20 feet.

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- **Plant Establishment**

Tree and/or shrub plantings shall follow site preparation/weed control for establishment, planting dates, planting and storage guidelines as detailed in FOTG (612) *Tree/Shrub Establishment.*

The planting of a riparian buffer shall establish a minimum of 300 trees/acre using one of the planting and/or establishment methods as detailed in FOTG (612) *Tree/Shrub Establishment*.

If seedlings are planted a minimum of 436 trees/acre shall be planted using a 10' X 10' spacing or equivalent.

Criteria to Create Shade to Lower Water Temperatures to Improve Habitat for Aquatic Organisms

Buffer species shall be capable of achieving desired height and crown density required for shade production. The buffer canopy shall be established to achieve at least 50% crown cover with an average projected canopy shade length equal to or greater than the planned width of the water body that needs shade protection. Use Table 2, Shadow Length Table as a tree height guide with Table 3, on pages 4-5 to select suitable species.

Place trees and shrubs with high shade values nearest the water course or body. Shoreline or channel relief (e.g. deeply incised channels) and topographic shading will be taken into account in selecting species.

Table 2. Shadow Length Table[1]

Tree Height (ft.)	June	July	August
40	23	25	32
50	29	31	40
60	35	38	48
70	41	44	56
80	47	50	64
90	52	57	72

[1]Shadow length at 10 AM and 2 PM, from the ASHRE Handbook, 1972

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

Table 3. - Plant List for Riparian Buffers (see page 5 for definitions of abbreviations used in this table)

Common Name/ Scientific Name	**Indiana Suitability**	**Flood Tolerance**	**Large Debris**	**Soil Drainage**	**Shade Value**	**Mature Height**	**Wildlife**		
							Food	**Cavity Nesting**	**Bat Roost**
Ash, Green *Fraxinus pennsylanica*	All	H	M	VPD-WD	H	60	M	M	M
Ash, White *Fraxinus americana*	All	M	M	MWD-WD	H	70	M	M	M
Baldcypress *Taxodium distichum*	So. IN[1]	VH	M	VPD-WD	M	80	M	M	M
Birch, River *Betula nigra*	All	M	H	VPD-WD	M	50	M	M	M
Blackgum *Nyssa sylvatica*	All	M	M	PD-WD	H	60	H	M	M
Buttonbush *Cephalanthus occidentalis*	All	VH	L	VPD-SPD	L	5	H	L	L
Cherry, Black *Prunus serotina*	All	L	M	MWD-WD	L	70	H	L	M
Chokeberry, Black *Aronia melanocarpa*	All	L	L	SPD-WD	L	10	H	L	L
Cottonwood *Populus deltoides*	All	H	H	PD-ED	M	90	L	H	M
Cranberry, Highbush *Viburnum trilobum*	All	L	L	VPD-WD	L	9	H	L	L
Dogwood, Red-Osier *Cornus stolonifera*	All	H	L	VPD-WD	L	10	H	L	L
Dogwood, Silky *Cornus amomum*	All	H	L	VPD-WD	L	10	H	L	L
Elderberry *Sambucus canadensis*	All	H	L	VPD-WD	L	9	H	L	L
Hickory, Shellbark *Carya laciniosa*	All	M	M	VPD-WD	H	70	H	M	H
Hackberry *Celtis occidentalis*	All	M	M	SPD-WD	M	50	M	M	M
Maple, Red *Acer rubrum*	All	H	H	VPD-WD	H	70	M	H	M
Maple, Silver *Acer saccharinum*	All	H	H	VPD-WD	H	80	M	H	M
Oak, Bur *Quercus macrocarps*	All	H	M	PD-ED	H	80	H	H	M
Oak, Cherrybark *Quercus pagodafolia*	So. IN[1]	M	M	SPD-WD	H	75	H	H	M
Oak, Pin *Quercus palustris*	All	H	H	VPD-WD	M	75	H	H	M

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

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Common Name/ Scientific Name	Indiana Suitability	Flood Tolerance	Large Debris	Soil Drainage	Shade Value	Mature Height	Wildlife		
							Food	Cavity Nesting	Bat Roost
Oak, Overcup *Quercus lyrata*	So. IN[1]	VH	M	VPD-WD	M	70	H	H	M
Oak, Red *Quercus rubra*	All	L	H	MWD-WD	H	80	H	H	M
Oak, Swamp Chestnut *Quercus michauxii*	So. IN[1]	M	H	SPD-WD	H	70	H	H	M
Oak, Swamp White *Quercus bicolor*	All	M	M	VPD-WD	H	70	H	H	M
Oak, White *Quercus alba*	All	L	H	MWD-WD	H	90	H	H	M
Pawpaw *Asimina triloba*	All	L	L	SPD-WD	L	20	M	L	L
Pecan *Carya illinoensis*	So. IN[1]	H	M	SPD-WD	H	120	H	H	M
Persimmon *Diospyros virginiana*	All	M	M	MWD-WD	M	50	H	M	M
Sweetgum *Liquidambar styraciflua*	So. IN[1]	M	M	PD-WD	M	85	L	M	M
Sycamore *Platanus occidentalis*	All	H	H	PD-WD	H	90	L	H	M
Tuliptree (Yellow Poplar) *Liriodendron tulipifera*	All	L	M	PD-WD	M	90	M	M	M
Walnut, Black *Juglans nigra*	All	M	M	MWD-WD	M	80	H	M	M
Willow, Black *Salix nigra*	All	VH	L	VPD-WD	L	60	L	M	M
Willow, Peachleaf *Salix amygdaloides*	All	VH	L	VPD-WD	L	30	L	L	L
Willow, Pussy *Salix discolor*	All	VH	L	VPD-WD	L	20	L	L	L
Willow, Sandbar *Salix interior*	All	VH	L	VPD-WD	L	10	L	L	L

[1]Counties south of U.S. 40

Letter Definitions

H	High
M	Medium
L	Low

Soil Drainage Class

VPD	Very Poorly Drained
PD	Poorly Drained
SPD	Somewhat Poorly Drained
MWD	Moderately Well Drained
WD	Well Drained

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

Indiana NRCS FOTG, February 2004

Criteria to Provide a Source of Detritus and Large Woody Debris for Aquatic and Terrestrial Organisms

Within Zone 1, establish, favor or manage species capable of producing stems and limbs of sufficient size to provide an eventual source of large woody debris (>10 inches in diameter) for in-stream habitat for fish and other aquatic organisms.

Refer to Table 3 on page 4 and 5 for species recommendations.

Criteria to Create Riparian Habitat and to Establish Corridors for Wildlife

The riparian forest buffer shall be planned for the target wildlife species. Woody plants shall be selected from Table 3, and/or from FOTG (645) *Upland Wildlife Habitat Management* and/or from FOTG (644) *Wetland Wildlife Habitat Management.* Refer to Table 4. for the minimum buffer widths for applicable wildlife species.

Table 4. Buffer Widths (minimum) for Selected Species

Species	Minimum Width, feet
Bald eagles, herons, egrets and cranes	600
Pileated woodpeckers, barred owls	450
Beaver, mink, waterfowl	300
Gray and fox squirrels	300
Deer	200
Amphibians and aquatic reptiles	50

Criteria to Reduce Sediment, Nutrients, Pesticides in Surface Runoff and to Provide Protection Against Scour Erosion within the Floodplain.

- To reduce sediment outflow the design width of Zone 2 shall be increased to include areas of debris and/or sediment deposits not to exceed the width of the 100 year flood plain. When Zone 2 cannot be increased Zone 3 shall be established to a minimum width of 20 feet.
- Manage the dominant tree canopy to maintain the vigor of the overstory and understory species. Periodic thinning may be required to allow adequate light to reach the forest floor to maintain a good cover of herbaceous plant species.
- The design with of Zone 2 shall be increased to include areas of overland flow, scour erosion, and overland flow channels up to the width of the 100 year floodplain

Criteria to Provide a Harvestable Crop of Timber and to Increase Carbon Storage

The riparian buffer shall be established and managed for timber products without compromising the buffers ability to support other planned criteria.

To promote rapid canopy closure and to produce a forest containing well-formed trees a minimum of 544 trees/acre shall be planted (8' X 10' spacing or equivalent) or established using direct seeding methods.

All timber harvesting activities shall be in compliance with the "Indiana Logging and Forestry Best Management Practices - BMP Field Guide"

CONSIDERATIONS

Consider the landowners objectives for riparian forest buffer, so that the planned objective for the planting is achievable.

Bare root seedlings should be considered as the standard method to establish trees and shrubs.

Planting bare root seedlings has proven to be the most economical and successful method to establish trees and shrubs. However, other methods to establish trees and shrubs may be applicable in some circumstances.

Seed sources for direct seeding and woody planting stock should be locally adapted and come from no more than 200 miles north or south of the planting site.

Consider selecting species from Conservation Tree/Shrub Suitability Groups (CTSG), species to plant, Section II (FOTG). Trees to plant from CTSG's can be viewed at the NRCS Indiana web site.

Monocultures and off site species are discouraged for riparian forest buffers.

Consider using a support stake when planting container trees and balled and burlapped stock.

Consider planting a mixture of species (5-10 species) adapted to the site (including shrubs) to improve plant diversity.

Seek technical assistance from a professional forester for reforestation or other conservation tree planting projects.

To improve plant growth, consider 2 additional years of chemical weed control after plants are established. Weed control should be performed using narrow bands (2'-3' wide) on each side of a plant row unless the entire site is treated.

Fine hardwood species should be mixed with other tree species and shrubs to promote diversity.

Sites that are frequently flooded or ponded for long or very long duration may be difficult and impractical for tree/shrub establishment.

Consider using natural regeneration on these sites to establish woody plants and allow the site to revegetate to herbaceous and/or woody plant cover.

Consider that natural regeneration is often likely to occur, but not guaranteed on sites that have a seed source from a forested floodplain system where seeds are deposited in sufficient quantity to establish woody vegetation. On these sites, natural regeneration of light seeded species (e.g. green ash, silver maple, cottonwood , etc.) may establish large numbers of tree seedlings.

Consider selecting species from FOTG Wildlife Upland Habitat Management (645) and/or FOTG Wetland Wildlife Habitat Management (644) to enhance wildlife benefits.

Shrub species may be direct seeded to provide wildlife habitat. Refer to Direct Seeding of Shrubs, IN-NRCS, Forestry Technical Note No. 16.

When planning this practice, consider how it can enhance and/or protect air quality.

PLANS AND SPECIFICATIONS

Plans and specifications for tree/shrub establishment will be prepared for each site in accordance with the criteria for this practice. The plan will include planting dates, site preparation, weed control, plant spacing, species, type of stock used, and planting and storage guidelines.

OPERATION AND MAINTENANCE

Check survivability of planted species after 3 years to insure that at least 300 desirable stems/acre of woody plants are established. If less than 300 stems/acre are established additional planting will be completed if it is determined that additional natural regeneration will not be sufficient to colonize the site within an acceptable time frame (usually 5 years).

Control weed competition during establishment (3 years). Competing weeds, brush, and vines can adversely affect survival, form and rate of tree growth. Additional years of weed control may be needed in some instances e.g. to control johnsongrass, quackgrass, or other hard to control weed species.

Use the following or combination of methods as needed to control weed competition (see Table 1 for specific treatments, FOTG (612) *Tree/Shrub Establishment*):

- shallow cultivation
- mowing
- spraying approved herbicides
- cutting woody plants and applying approved pesticides

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

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Correlatively prune hardwood species, as needed depending on species and growth form desired. Refer to FOTG (660) *Tree Shrub Pruning*.

Protect the planting from fire. Plan access roads and firelanes prior to planting. See Indiana Field Office Technical Guide, Section IV for *Access Road* (560) and *Firebreak* (394).

Fence if necessary to protect the planting from excessive livestock browsing and trampling damage, refer to FOTG Standards, Use Exclusion (472) and Fence (382).

Protect from disease, rodents, deer, and insects using approved pesticides, hunting, fencing, or other appropriate methods. Additional information can be viewed from the "Illinois Direct Seeding Handbook", Wildlife Damage Management.

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Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

Indiana NRCS FOTG, February 2004

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

Sediment Basin

(Number)

Code 350

DEFINITION

A basin constructed to collect and store debris or sediment.

PURPOSES

To preserve the capacity of reservoirs, ditches, canals, diversions, waterways, and streams; to prevent undesirable deposition on bottom lands and developed areas; to trap sediment originating from construction sites; and to reduce or abate pollution by providing basins for deposition and storage of silt, sand, gravel, stone, agricultural wastes, and other detritus.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies where physical conditions or land ownership preclude treatment of a sediment source by the installation of erosion control measures to keep soil and other material in place, or where a sediment basin offers the most practical solution to the problem.

CRITERIA

General. The capacity of the sediment basin shall equal 1 ½ times the volume of sediment expected to be trapped at the site during the planned useful life of the basin or the improvements it is designed to protect. If it is determined that periodic removal of debris will be practicable, the capacity may be proportionately reduced.

Agricultural Lands – The minimum volume of sediment storage for permanent sediment basins in agricultural areas shall be a 1 ½ times the estimate determined for a 15-year period or the period required for stabilization of the sediment source area.

The procedure outlined in Chapter 11 of the Engineering Field Manual will be used to determine the amount of sediment, which will accumulate in a basin.

Disturbed Areas – The minimum sediment storage volume shall be 1 ½ times that expected from the source area during the expected life of the structure. When periodic cleanout is planned, the minimum storage volume will be 1 ½ times that required for the expected period between cleanout but not less than that required for one year. Consult procedure outlined in Chapter 11 of the Engineering Field Manual.

Classification. Sediment Basins shall be classified as follows:

Class 1 –
1. Drainage Area, 5 acres or less
2. No permanent pool
3. Embankment effective height 5 feet or less
4. Temporary basin

Class II – Any sediment basin exceeding one or more of the criteria for Class I sediment basins.

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

Indiana NRCS FOTG – November 1989.

<u>Class I basins</u>. The minimum capacity shall be that required to store all of the runoff from a 10-year, 24-hour storm from the contributing drainage area plus the required sediment storage.

The embankment shall have a minimum top width of 4 ft and side slopes of 2:1 or flatter.

An outlet shall be provided of earth, pipe, stone, or other devices adequate to keep the sediment in the basin and to handle the 10-year frequency discharge without failure or significant erosion. Outlet conduits shall meet the standard and specifications for ponds (378).

The detention time of the basin affects the efficiency of sediment removal from the incoming runoff. The minimum detention time should be 24 hours. This may be met by providing a maximum design outflow of 0.025 c.f.s. per acre-inch of runoff. Longer detention times are encouraged where practical or necessary to meet downstream water quality.

An emergency spillway is not required. A maximum of one foot may be added to the design height across the central storage area to provide for an emergency spillway around one or both ends of the embankment.

<u>Class II basins</u>. The basin may be either a wet type or dry type. The principal spillway and drawdown if used, shall be proportioned such that the inflow from a 10-year, 24-hour storm is detained a minimum of 24 hours.

<u>Other provisions</u>. Provisions are to be made for draining sediment pools if necessary for safety and vector control. Fencing and other safety measures shall be installed as necessary to protect the public from floodwater and soft sediment. Fencing shall be according to NRCS Standard 382.

The design of dams, spillways, and drainage facilities shall be according to NRCS standards for ponds (378) and grade stabilization structures (410) or according to the requirements in TR-60, as appropriate for the Class II and kind of structure being considered.

<u>Other Factors to Consider to Improve Efficiency</u>

Provisions at the entrance of a basin to reduce velocity of inflow.

Attempt to achieve a basin flow length to width ratio of 5 to 1.

Use a siphon arrangement in a nonperforated riser pipe.

Locating inflow and outflows as far apart as possible to prevent short-circuiting.

The use of baffles within the basin to help utilize the whole basin.

<u>"Surface Mining Control and Reclamation Act of 1977"</u>

Sediment basins designed to meet the sedimentation pond regulations of the above act shall also be designed to meet the following:

1. Provide a minimum of 3 years sediment storage volume.

2. Sediment storage volume equal to 0.1 acre feet per acre of disturbed area within the upstream drainage area, except that sediment volumes of no less than 0.035 acre-foot for each acre may be used where other sediment control measures equals the reduction in sediment storage volume for a total of 0.1 acre feet per acre of disturbed area.

3. Less than 24-hour theoretical detention time may be approved by regulatory authority to not less than 10 hours by demonstrated mechanical improvements or to any level by chemical treatment that meets effluent limitations.

4. The dewatering device shall not be located at a lower elevation than the maximum elevation of the design sediment storage volume.

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5. Sediment shall be removed from sedimentation basins when the volume of sediment accumulates to 60 percent or more of the designed sediment storage volume.

6. Emergency Spillway shall be at or above the 10-year, 24-hour precipitation event.

7. An appropriate combination of principal and emergency spillway shall be provided to discharge safely the runoff from a 25-year, 24-hour precipitation event.

8. The emergency spillway shall be a minimum of one foot above the crest of the principal spillway.

9. If the embankment has more than 20 feet vertical height between the elevations of ground at the upstream toe and the crest of the emergency spillway or has a storage volume of 20 acre feet or more, an appropriate combination of principal and emergency spillway shall be provided to safely discharge the runoff resulting from a 100-year, 24-hour precipitation event. Indiana Department of Natural Resources criteria will apply as appropriate.

Vegetation. The exposed surfaces of the embankment, earth spillway, borrow area, and other areas disturbed during construction shall be seeded or sodded.

Seedbed preparation, seeding, fertilizing, and mulching shall be according to the Standards and Specifications for Critical Area Planting (342).

CONSIDERATIONS

Sediment basins should be part of the treatment needed to protect the soil, water, plants, animals and air resources. The management system must be planned to prevent excessive maintenance and operation problems.

Effects on water quantity and quality shall be considered. Sediment basins are a flow through type structure and are designed to detain the runoff, but not to store it. Therefore, the structure will not decrease the amount of surface runoff water delivered downstream, but will delay the time it takes the runoff to reach the downstream areas. There may be an increased recharge to ground water, depending on the time of detention, the permeability of the bottom of the basin, and the age of the structure.

If the basin has been in place a long enough time to collect a considerable amount of organic material in the bottom, and the bottom tends to remain wet; the bottom may be nearly impermeable. In this situation, there will be only small amounts of water percolating to beneath the basin.

Sediment basins will retain sediment, sediment associated materials and other debris from the water. Due to the detention of the runoff in the basin, there is an increased opportunity for soluble materials to be leached toward the ground water.

Special attention shall be given to maintaining and improving visual resources and habitat for wildlife where applicable. The landowner/user shall be advised if wetlands will be affected and USDA-NRCS wetland policy will apply. All work planned shall be in compliance with General Manual Title 450-GM, Part 405, Subpart A, Compliance with Federal, State, and Local Laws and Regulations. If archaeological and historical properties are encountered, the USDA-NRCS policy in General Manual Title 420-GM, Part 401 shall be followed.

PLANS AND SPECIFICATIONS

Plans and specifications for installing sediment basins shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

Construction of sediment basins within the scope of the standard for ponds (378) shall have, as a minimum, specifications commensurate with those for ponds (378). Those within the scope of TR-60 shall be in accord with the guide specifications contained in the National Engineering Handbook, Section 20.

OPERATION AND MAINTENANCE

A maintenance program shall be established by the landowner/user to maintain capacity and vegetative cover. Items to consider are:

1. Do not graze protected area of embankment and pond.

2. Fertilize to maintain a vigorous vegetative cover in protected area.

3. Mulch, spray or chop out undesirable vegetation periodically to prevent growth of large woody-stemmed weeds, water plants such as cattails or trees (such as willows) from embankment and spillway areas.

4. Promptly repair eroded areas.

5. Promptly remove any burrowing rodents that may invade area of embankment.

6. Reestablish vegetative cover immediately where scour erosion has removed established seeding.

7. Keep open all spillways and remove trash that may accumulate around entrance.

8. Remove sediment from basin when volume of sediment storage becomes depleted.

9. Periodically inspect area for any new maintenance items and if any observed take immediate action to protect from further damage or deterioration.

Indiana NRCS FOTG – November 1989.

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

Streambank and Shoreline Protection

(Feet)

Code 580

DEFINITION

Using vegetation or structures to stabilize and protect banks of streams, lakes, estuaries, or excavated channels against scour and erosion.

PURPOSES

To stabilize or protect banks of streams, lakes, estuaries, or excavated channels for one or more of the following purposes:

1. To prevent the loss of land or damage to utilities, roads, buildings, or other facilities adjacent to the banks,
2. To maintain the capacity of the channel,
3. To control channel meander that would adversely affect downstream facilities,
4. To reduce sediment loads causing downstream damages and pollution, or
5. To improve the stream for recreation or as a habitat for fish and wildlife.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies to natural or excavated channels where the streambanks are susceptible to erosion from the action of water, ice, or debris or to damage from livestock or vehicular traffic. It also applies to controlling erosion on shorelines where the problem can be solved with relatively simple structural measures, vegetation, or upland erosion control practices and where failure of structural measures will not create a hazard to life or result in serious damage to property.

CRITERIA

<u>Criteria for streambank protection measures</u>

Because each reach of a channel, lake, or estuary is unique, measures for streambank and shore protection must be installed according to a plan adapted to the specific site.

Designs for streambanks shall be according to the following principles:

1. Protective measures to be applied shall be compatible with improvements planned or being carried out by others.

2. The grade must be controlled, either by natural or artificial means, before any permanent type of bank protection can be considered feasible, unless the protection can be safely and economically constructed to a depth well below the anticipated lowest depth of bottom scour.

3. Streambank protection shall be started at a stabilized or controlled point and ended at a stabilized or controlled point on the stream.

4. Channel clearing to remove stumps, fallen trees, debris, and bars that force the streamflow into the streambank shall be an initial element of the work.

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

Indiana NRCS FOTG – August 1992.

5. Changes in channel alignment shall be made only after an evaluation of the effect on the land use, interdependent water disposal systems, hydraulic characteristics, and existing structures.

6. Structural measures must be effective for the design flow and be able to withstand greater floods without serious damage. They shall also be designed to avoid an increase in erosion downstream of planned measures.

7. When the streambank protection is to protect improvements such as buildings or structures, consideration will be given to items such as: (a) cost of the stabilization compared to the value of the structure(s) protected, (b) possibility of relocation of the structure needing protection, (c) remaining service life of the structure needing protection, and (d) effect of the streambank stabilization of the future management system of the landowner/user.

8. Extensive clearing of trees and brush along channel banks for the purpose of placing streambank protection will not be performed. Clearing under the area which streambank protection is to be placed is permissible. If removal of trees and brush is required, only the minimum necessary to accomplish the work will be performed. Lack of proper equipment to place the riprap or reduce construction costs are not justifiable reasons for removing more woody vegetation than absolutely necessary.

9. Vegetative protection shall be considered on the upper parts of eroding banks, especially on areas that are susceptible to infrequent inundation. When the 10-year frequency flow or the bank full flow has a velocity of 5 ft. per second or less, riprap or other nonerosive material to stabilize only the toe of the slope may be placed if all of the following conditions are met: (a) the upper edge or line of stabilizing material is 1 foot or more above the zone of saturation for base flow conditions on the bank slope, (b) banks have a slope of 2:1 or flatter, (c) the watershed or drainage area upstream from the area being protected is less than 100 square miles in size.

10. Scrap materials such as junked auto bodies will not be used for streambank or shoreline protection.

Streambank protection measures. The following is a partial list of elements that may be in a plan for streambank protection.

___Removal of fallen trees, stumps, debris, minor ledge outcroppings, and sand and gravel bars that may cause local current turbulence and deflection.

___Removal of trees and brush that adversely affect the growth of desirable bank vegetation.

___Reduction of the slope of streambanks to provide a suitable condition for vegetative protection or for the installation of structural bank protection.

___Placed or dumped heavy stone, properly underlain with a filter blanket, if necessary, to provide armor protection for streambanks.

___Deflectors constructed of posts, piling, fencing, rock, brush, or other materials that project into the stream to protect banks or curves and reaches subjected to impingement by high velocity currents.

___Pervious or impervious structures built on or parallel to the stream to prevent scouring streamflow velocities adjacent to the streambank.

___Obstructions, such as fences, to protect vegetation needed for streambank protection or to protect critical areas from damage from stock trails or vehicular traffic. Where needed, construct a permanent fence capable of excluding livestock from the streambanks. If livestock watering places are provided, the ramps leading to low water shall be on a slope of 4:1 or flatter. The ramps shall be surfaced with a suitable material to prevent erosion. Floodgates may be used at channel crossings, property and other fence lines.

___Banksloping. All banks to be seeded only and not riprapped shall be sloped to a 2:1 side slope or flatter. All material excavated from a sloped bank may be placed on the bank, leveled, and seeded to prevent erosion during high water or hauled to other areas for use. Excavated material should not be pushed into the stream or lake or form barriers which interfere with runoff entering natural channels.

___Jetties. Brush, riprap, and/or piles may be used as deflecting jetties. Jetties must not extend out in the stream so the channel capacity is reduced.

___Revetments.

(1) Riprap. This type of construction is particularly effective in the following situations: (a) sharp bends; (b) constrictions such as bridges where velocities are increased; (c) along the opposite bank where another stream junctions; and (d) on large streams, the bank should be sloped to a 1 ½ side slope or flatter. The thickness and gradation requirements shall conform to criteria in Chapter 16 of the Engineering Field Manual.

(2) Gabions. Gabions are wire or plastic mesh baskets connected together and filled with rock in place. Banks shall be sloped to a 1.5:1 side slope or flatter. If the bank material is a fine-grained soil, use a well-graded pit-run sand and gravel filter or filter cloth.

___Stream Crossings. Stream crossings are installed to provide crossings for equipment and/or livestock. The crossing may consist of rubble or paved surfaces placed on the stream bottom and sides or may be culverts or bridges. NRCS does not provide designs for bridges. However, standard plans for timber bridges are available. Bridges and culverts must meet the requirements for capacity required by the Indiana Department of Natural Resources. Permits are usually required.

Crossing consisting of rock or rubble shall be placed in a manner which does not interfere with streamflows. Adequate thickness shall be provided to insure a firm base.

The following minimum guidelines shall apply for stream crossings:

(1) Firm Foundations - use on of the following:

a. 5 inches concrete over a minimum of 6 inches of pit-run sand-gravel or crushed stone.

b. 4 inches of surface gravel (IDOH size #5, #53 or #73) over 8 inches or more of crushed rock (d_{50} = 4”).

(2) Soft Foundations – use one of the following:

a. 5 inches concrete with 6 gate, 6” x 6” welded wire fabric over 6 inches pit-run sand and gravel or crushed stone.

b. 4 inches of surface gravel (IDOH size #5, #53 or #73) over 18 inches or more of crushed rock (d_{50} = 7-8”).

Crushed rock thickness should be increased 6 inches for equipment or vehicle crossings.

Concrete crossings shall be finished with a rough surface.

Ramps for livestock crossings shall not be steeper than 4 horizontal to 1 vertical. Ramps for equipment should be 6 horizontal to 1 vertical or flatter. Minimum width is 8 feet. Side slopes for ramps shall not be steeper than 2 horizontal to 1 vertical.

Standard plans shall be used when applicable.

Criteria for shoreline protection measures.

Design shall be according to the following principles.

1. Treatment depends on soil type and the slope characteristics both above and below the waterline. Slope characteristics below the waterline shall be representative of the slope for a minimum distance of 50 ft. from the shore.

2. End sections shall be adequately bonded to existing measures or terminate in stable areas.

3. Design water surface shall be the mean high tide or, in nontidal areas, the mean high water.

4. Control of surface runoff and internal drainage shall be considered in the design and installation of all protection measures.

5. Protection measures to be applied shall be compatible with improvements planned or being carried out by others.

6. No work of improvement may increase the potential for erosion on an adjacent reach of shoreline.

Shoreline protection measures. The following is a partial list of protection measures that may be used.

___Bulkheads (timber, metal piling, concrete, concrete block).

___Revetments (prefabricated slope protection blocks, riprap, soil cement, piling).

___Groin systems (timber or concrete).

___Vegetation of the type that will grow across or along the waterline.

___Bank Sloping. All banks to be stabilized shall be sloped to a 2:1 slope or flatter. All material excavated from sloped banks should be placed on the bank, leveled and seeded to prevent erosion from runoff or wave runup or hauled to other areas for use. Excavated materials shall not be pushed into the lake.

___Beaching Slope. Shore protection with beaching slopes utilizes the movement of semi-fluid sands up the beach with breaking waves, and off the beach with receding waves to dissipate energy. For any given wave size, a beach will stabilize with a particular relationship between beach slope and the median grain size of beach material. Criteria for design of beaching slope is contained in Chapter 16 of the Engineering Field Manual.

Requirements for the design of beaching slopes are:

1. The median grain size of the material larger than 0.17mm is used to represent the material.

2. The minimum median grain size material used shall be 0.5mm.

3. Minimum thickness of blanket is 1 foot.

4. Extend the slope protection below still water elevation a distance of two times the design wave height.

5. Extend protection above still water elevations a distance equal to the computed runup plus one foot.

6. Materials shall be place according to the thickness, slope and gradation contained in Chapter 16 of the Engineering Field Manual.

___Riprap. This type revetment protects shorelines from wave action, ice action and slumping due to seepage. Riprap shall be placed between 1.5 times the wave height below the still water surface and the runup plus 0.5 feet above the still water surface. The wave height (H) may be determined from Table 1. The runup (R) may be determined by multiplying the ratio (R/H) in Table 2 by the wave height (H). The D_{50} rock size in inches for various slopes and wave heights is shown in Table 3.

Table 1 – Wave Heights*

Fetch Distance (F) (ft)	Wave Height (H) (ft)
500	0.7
1,000	1.0
1,500	1.2
2,000	1.4
3,000	1.7
4,000	1.9
5,000	2.1
7,500	2.6
10,000	3.0
12,500	3.3

*H = 0.0392 F
Wind velocity = 50 mph

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Table 2 – Ratio of Runup (R) Wave Height (H) for Various Shore Slopes

Shore Slope	Ratio
Horizontal:Vertical	R/H
2:1	2.3
3:1	1.9
4:1	1.5
6:1	0.9
10:1	0.5

Table 3 – D50 Rock Size for Various Shore Slopes and Wave Heights

Shore	Wave	D_{50}
Slope	Height (H)	Size
(Horz:Vert)	(ft)	(in)
2:1	1.0	4
	2.0	6
	3.0	8
3:1	1.0	4
	2.0	5
	3.0	7
4:1	1.0	4
	2.0	4
	3.0	7
6:1	1.0	4
	2.0	4
	3.0	6
10:1	1.0	4
	2.0	4
	3.0	4

Riprap shall be well graded with:

Percent passing by weight	Size
(%)	(inches)
100	2 x D_{50}
50-89	1.5 x D_{50}
25-50	D_{50}
10-30	0.5 x D_{50}
10	0.25 x D_{50}

A layer of bedding material no less than 6 inches thick or filter fabric is required on erodible soils. The bedding material shall be: 40-60% gravel (max. 3”); 40-60% sands; less than 5% finer than the #200 sieve.

On slopes 6 horizontal to 1 vertical and steeper, the riprap shall be anchored at the lowest elevation by excavating a “key-way” to a depth of 2 x D_{50} or increasing the thickness to 4 x D_{50} for a horizontal distance of 8 x D_{50}.

___Gabions. Gabions are wire or plastic mesh baskets connected together and filled with rock in place. They are flexible and stable if properly designed and installed. Like riprap, the apron will settle and conform to the final lake bed contour. Banks shall be sloped to a 1.5:1 side slope or flatter.

___Concrete. Concrete revetments for shore protection may be either (1) a sloping concrete apron which provides a nonerosive surface for waves to break against and run up on, or (2) a bulkhead type revetment used where steep banks prohibit the use of sloping forms of protection. The force of the waves acts on the bulkhead primarily in a horizontal direction. Footings for these structures should extend a minimum depth of 3 times the wave height below still water elevation. The top of the revetment should extend a minimum of 1 foot plus runup above still water elevation.

___Piling. Piling is another type of revetment used where natural shorelines are too steep for sloping protection. Piling may be installed either vertically or with a slight batter. Minimum thickness for piling are:

Material	Minimum Thickness (inches)
Metal Sheet	0.109
Wood Plank	2.0
Wood Pole	4.0

Wood planks and poles shall be pressure treated. The land side of piling should be backfilled to absorb wave energy. For design of piling, the lake bottom may be considered stable at a depth of three times the wave height below still water elevation. The top of the piling should be 1 foot plus runup above still water elevation.

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___Groins. Groins are used to replace beach material removed by long shore currents. With the beach restored, waves break further from shore, reducing erosion on the bank. Groins are effective only where appreciable long shore currents exist. If the amount of sand carried by long shore currents (littoral drift) is small, the areas between groins may have to be artificially filled to establish a beach. Since the placement of groins tends to increase erosion on unprotected downdrift reaches of shoreline, location must be selective. Groins may be built of riprap, timber, steel, or gabions.

Vegetative protection. Vegetation will be established on all disturbed areas such as channel and shoreline slopes, berms, spoil and other areas except where the slopes are permanently covered with water or where streambank or shoreline protection measures are placed or land use conditions are such that vegetation is impractical. Seedbed preparation, seeding, fertilizing, and mulching shall comply with practice standard Critical Area Planting (342). The vegetation shall be maintained and tree and brush controlled by hand, machine or chemicals as needed.

CONSIDERATIONS

Effects on water quantity and quality shall be considered. This practice will have a minor effect on the quantity of surface and ground water. There may be increased erosion and sediment yield from the area and surrounding areas during and immediately after construction. There should be minimal effect after the first period of use and establishment of the protection and vegetation of disturbed areas. This practice will decrease the flow and base load of the stream on which it is applied to protect the streambanks. When it is installed to protect shorelines, there can be local enhancement of water quality, but, generally, the shoreline is protected and there are only slight benefits on water quality.

Special attention shall be given to maintaining and improving visual resources and habitat for fish and wildlife where applicable. The landowner/user will be advised if wetlands will be affected and USDA-NRCS wetland policy will apply. All work planned shall be in compliance with General Manual title 450-GM, Part 405, Subpart A, Compliance with Federal, State, and Local Laws and Regulations.

Consideration shall be given to the use of construction materials, grading practices, vegetation, and other site development elements that minimize visual impacts and maintain or complement existing landscape uses such as pedestrian paths, climate controls, buffers, etc.

PLANS AND SPECIFICATIONS

Plans and specifications for streambanks and shoreline protection shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

Construction specifications

General. Construction operations shall be carried out in such a manner and sequence that erosion and air and water pollution will be minimized and held within acceptable limits. Construction methods that enhance fish and wildlife will be used where practical. Trees, stumps, and brush removed from the construction area may be piled for fish and wildlife habitat when approved by the landowner/user.

The completed job shall present a workmanlike appearance and conform to the line, grades, and elevations shown on the drawings or as staked in the field.

All operations shall be carried out in a safe and skillful manner. Safety and health regulations shall be observed and appropriate safety measures used.

Site preparation. Special attention shall be given to protecting and maintaining key shade, food, den trees, and visual resources. Removal of any trees and brush shall be done in such a manner as to avoid damage to other trees and property.

All trees, stumps, brush, and similar materials are to be removed from the site or disposed of in such a way as to have the least detrimental effect on the environment.

Excavation. To the extent needed, all suitable materials removed from the specified excavation shall be used in the construction of the earth fill areas of the protection. All surplus or unsuitable materials shall be disposed of in a manner that will not interfere with the functioning of the protection.

Fill placement. Material placed in the fill areas of the protection shall be free of detrimental amounts of sod, roots, frozen soil, stones over 6 inches in diameter and other objectionable material. To the extent they are suitable, excavated materials are to be used as fill. The distribution and gradation of materials shall be such that there will be no lenses, pockets, streaks, or layers of material differing substantially in texture or gradation from the surrounding material.

Moisture control. The minimum moisture content of the fill material and foundation shall be such that, when kneaded in the hand, the fill material will form a ball, which does not readily separate. The maximum moisture content is when conditions are too wet for efficient use of the hauling and compaction equipment.

Topsoiling. Topsoil shall be removed and stockpiled on areas where establishment of vegetation is a problem on exposed subsoils (all subsoils except loam, silt loam and sandy loam, except where dense till is present). Topsoil shall be respread to provide a seedbed.

Where subsoil is exposed or is used in construction, topsoil will be placed in accordance with the following criteria.

- A minimum of four inches of topsoil ("A" horizon) will be placed where six or more inches of friable soil material with good moisture holding properties (more than 0.15 inches per inch) lies below the surface of the constructed surface.

- A minimum of eight inches of topsoil ("A" horizon) will be placed where less than six inches of friable soil materials with good moisture holding properties (more than 0.15 inches per inch) lies below the surface of the constructed surface.

- Topsoil will be placed in final shaping operations. The underlying soil, if needed, will be chiseled or scarified to permit proper bonding of topsoil.

Materials. The riprap material shall conform to the gradation shown on the drawings and be a durable rock. Riprap shall be dumped or placed in the manner consistent with good construction procedures and to the lines and grades shown on the drawings.

The area to be covered with a filter fabric or filter blanket shall be reasonably smooth. An even thickness of filter material shall be placed on the prepared surface. Care shall be exercised when placing the riprap to insure that the blanket is not ruptured or displaced.

Wire mesh baskets, when used for gabions, shall be fabricated from corrosion-resistant material to contain the rock material. Durable rock shall be used to fill gabions. The maximum dimension of individual rock particles shall not exceed one-half the minimum basket dimension. Minimum rock dimensions shall exceed the mesh size used in the basket construction. Soft materials such as sandstone and shale shall not be used. The foundation shall be smoothed and filter material, if required, shall be properly placed under and behind the gabions. The baskets shall be assembled in accordance with the manufacturer's recommendations.

Finish and cleanup. Construction areas will be finished in a relatively smooth condition ready for seeding. All rocks 3" in diameter or larger and roots shall be removed from the areas.

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Vegetative establishment

Vegetation will be established on all disturbed areas such as channel and shoreline slopes, berms, spoil and other areas except where the slopes are permanently covered with water or when bank materials or land use conditions are such that vegetation is impractical. Trees and shrubs should be established where practical. Disturbed areas are to be seeded or planted to trees as soon as possible after exposure. Use daily seeding whenever possible. Planned trees and shrubs shall be established according to Technical Guide Specification 612, Tree/Shrub Establishment.

Gullied and uneven areas should be smoothed before attempting to prepare seedbed.

If needed, apply lime to raise the pH to the level desired for species of vegetation being seeded.

Fertilize according to soil tests or at a minimum rate of 1000 lbs. of 12-12-12 fertilizer (or its equivalent) per acre as soon as the measure has been constructed within the seeding periods. Apply 150 lbs. per acre of ammonium nitrate 6-8 weeks after seeding on soils low in organic matter and fertility.

Work the fertilizer and lime into the soil to a depth of 2-3 inches with a harrow or disk.

Prepare a firm seedbed with a cultipacker or cultipacker type seeder.

Seed one of the following grass mixtures during the preferred seeding periods of March 1 to May 10 or August 10 to September 30.

When construction is completed between May 11 and August 9, a temporary cover crop should be established using one of the following:

Species	Minimum Rates
(1) Wheat	150#/acre
(2) Rye	150#/acre
(3) Spring oats	100#/acre
(4) Annual rye grass	20#/acre
(5) Corn	150-300#/acre

After August 10, temporary cover shall be removed or incorporated, fertilizer applied, seedbed prepared and permanent seeding done in normal manner.

On critical sites, mulch with 1-1/2 to 2 tons straw per acre. Anchor the mulch with asphalt spray, netting or a mulch anchoring tool. In areas such as sharp breaks in shoreline or channel slopes or where excessive velocities could cause bank scour, paper netting, jute netting, rock lining, erosion control blankets or sod should be used.

Streambank and Shoreline Seed Mixtures

Species	Seeding Rate (PLS)		Suitable pH	Site Suitability		
	(lbs/ac)	(lbs/100 $ft^{2)}$		Droughty	Well-drained	Wet
1. Tall fescue	20	0.5	5.5 – 8.0	1	1	1
Smooth bromegrass	20	0.5				
2. Tall fescue	20	0.5	5.0 – 7.5	1	1	1
Reed Canarygrass	20	0.5				
3. Kentucky bluegrass	15	0.375	5.5 – 7.0	2	1	2
Creeping red fescue	15	0.375				
Redtop	3	0.07				
4. Tall fescue	30	0.75	5.0 – 7.5	2	1	1

PLS – Pure Live Seed
Site Suitability: 1 – Preferred, 2 - Acceptable

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Mixture 3 may be used through urban or similar areas where lower growing vegetation is desired and close mowing will be practiced, also withstands shade better.

Five pounds of crownvetch seed per acre may be added to mixtures 1, 2 or 4 where high banks will be infrequently flooded.

OPERATION AND MAINTENANCE

A maintenance program shall be established by the landowner/user to maintain capacity and vegetative cover. Items to consider are:

1. Do not graze protected area during vegetative establishment and when soil conditions are wet.

2. Fertilize to maintain a vigorous vegetative cover. Caution should be used in fertilization to maintain water quality.

3. Control tree and brush growth as needed by hand, mechanical or chemical means.

4. Promptly repair eroded areas in or adjacent to the protected area.

5. Reestablish vegetative cover immediately where scour erosion has removed established seeding.

6. Periodically inspect area for any undermining or instability. If any undermining or instability is observed, take immediate action to protect from further damage.

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NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

Stream Channel Stabilization

(Feet)

Code 584

DEFINITION

Stabilizing the channel of a stream with suitable structures.

PURPOSES

To control aggradation or degradation in a stream channel.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies to stream channels undergoing damaging aggradation or degradation that cannot be feasibly controlled by clearing or snagging, by the establishment of vegetative protection, or by the installation of upstream water control facilities.

CRITERIA

It is recognized that channels may aggrade or degrade during a given storm or over short periods. A channel is considered stable if over long periods the channel bottom remains essentially at the same elevation. The channel in hard bedrock may be considered stable, but the erosive energy will be expended on the softer alluvial bank materials, causing “skating” along the bedrock bottom.

In the design of a channel for stability, consideration shall be given to the following points:

1. The character of the materials comprising the channel bottom.

2. The quantity and character of the sediments entering the reach of channel under consideration. This shall be analyzed on the basis of both present conditions and projected changes caused by changes in land use or land treatment and upstream improvements or structural measures.

3. Streamflow peaks, velocities, and volumes at various flow frequencies.

4. The effects of changes in velocity of the stream produced by the structural measures.

Structures installed to stabilize stream channels shall be designed and installed to meet NRCS standards for the particular structure and type of construction.

<u>Vegetative establishment</u>

Vegetation will be established on all disturbed channel slope areas, berms, spoil and other areas according to Standards and Specifications Streambank and Shoreline Protection (580).

CONSIDERATIONS

Stream channel stabilization should be part of the treatment needed to protect the soil, water, plant and air resources. The management system must be planned to prevent excessive maintenance and operation problems.

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

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Effects on water quantity and quality shall be considered. This practice will have no significant change on the total volume of runoff or the potential for groundwater recharge. Water tables in areas adjacent to the practice may be altered causing changes in soil moisture storage, rooting depths and the transpiration rate of vegetation affected by the practice.

The surface disturbance of the construction area may temporarily increase the potential for erosion and delivery of sediment and sediment-attached substances to the stream. The constructed channel stabilization measure will provide a stable channel, and over time a decrease in sediment yield will result. Vegetation that is removed in the construction area to install the practice may reduce shade on the channel and water temperature may increase. The effect of the practice on aquatic communities residing in the channel would depend on the ecosystems present in the channel and adjacent area both before and after the construction and the length of time of the installation. The design of the stabilization measure should maintain or improve the quality of these fish and wildlife communities as far as can be compatible with the design and scope of the practice.

Special attention shall be given to maintaining and improving visual resources and habitat for fish and wildlife. The landowner/user shall be advised if wetlands will be affected and USDA-NRCS wetland policy will apply. All work planned shall be in compliance with General Manual, Title 450-GM, Part 405, Subpart A, Compliance with Federal, State, and Local Laws and Regulations. If archaeological and historical properties are encountered, the USDA-NRCS policy in General Manual, Title 420-GM, Part 401 shall be followed.

PLANS AND SPECIFICATIONS

Plans and specifications for stream channel stabilization shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

Construction specifications

The construction specifications for stream channel stabilization will be according to the construction specifications for Standards and Specifications Streambank and Shoreline Protection (580). In addition to these specifications, there should be an effort to preserve and/or plant adapted trees to provide shade to prevent thermal pollution, prevent willow encroachment, help stabilize banks and provide wildlife habitat in those areas of perennial flow or where woody cover exists.

OPERATION AND MAINTENANCE

A maintenance program shall be established by the landowner/user to maintain stream channel stabilization and vegetative cover. Items to consider are:

1. Do not graze protected area.

2. Fertilize to maintain a vigorous vegetative cover. Caution should be used in fertilization to maintain water quality.

3. Periodically inspect area of the measure for any undermining or instability and if any are observed take immediate action to protect from further damage.

4. Reestablish vegetative cover immediately where scour erosion has removed established seeding.

5. Control undesirable trees and brush growth around the stream channel stabilization as needed by hand, mechanical or chemical means. Use only chemicals labeled for this purpose.

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NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

SUBSURFACE DRAIN

(Feet)

Code 606

DEFINITION

A conduit, such as corrugated plastic tubing, tile, or pipe, installed beneath the ground surface to collect and/or convey drainage water.

PURPOSES

The purpose of subsurface drainage is to:

1. Improve the soil environment for vegetative growth, reduce erosion, and improve water quality by:
   a. regulating water table and ground water flows,
   b. intercepting and preventing water movement into a wet area,
   c. relieving artesian pressures,
   d. removing surface runoff,
   e. leaching of saline and sodic soils,
   f. serving as an outlet for other subsurface drains, and
   g. regulating subirrigated areas or waste disposal areas.
2. Collect ground water for beneficial uses.
3. Remove water from heavy use areas, such as around buildings, roads, and play areas; and accomplish other physical improvements related to water removal.
4. Regulate water to control health hazards caused by pests such as flukes, flies, or mosquitoes.

CONDITIONS WHERE PRACTICE APPLIES

This standard applies to areas having a high water table where the benefits of lowering the water table or controlling ground water or surface runoff justify installing such a system.

This standard applies to areas suitable for the intended use after installation of required drainage and other conservation practices. The soil shall have enough depth and permeability to permit installation of an effective and economically feasible system.

In areas where an outlet is available, either by gravity flow or by pumping, the outlet shall be adequate for the quantity and quality of effluent to be discharged. Septic tanks and other waste disposal systems shall not be connected directly to subsurface drain systems.

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

CRITERIA

General Criteria Applicable To All Purposes

The design and installation shall be based on adequate surveys and investigations. This practice shall comply with all Federal, State, and Local laws and regulations.

Capacity. One or more of the following shall determine the required capacity:

1. Application of drainage coefficients, as recommended by the Drainage and Wet Soil Management, Drainage Recommendations for Indiana Soils, AY-300, Purdue Extension, June 2001 or Chapter 14, Water Management (Drainage), Subchapter C, Subsurface Drainage of the Engineering Field Handbook (EFH) to the acreage drained, including added capacity required to dispose of surface water entering through inlets.
2. Yield of ground water based on the expected deep percolation of irrigation water from the overlying fields, including the leaching requirement.
3. Comparison of the site with other similar sites where subsurface drain yields have been measured.
4. Measurement of the rate of subsurface flow at the site during a period of adverse weather and ground water conditions.
5. Application of Darcy's law to lateral or artesian subsurface flow.
6. Estimates of lateral or artesian subsurface flow.

Size. The size of subsurface drains shall be computed by applying Manning's formula. The size shall be based on the required capacity and computed by using one of the following assumptions:

1. The hydraulic gradeline is parallel to the bottom grade of the subsurface drain with the conduit flowing full at design flow.
2. The conduit flowing partly full where a steep grade or other conditions require excess capacity.
3. Conduit flowing under pressure with hydraulic gradeline set by site conditions on a grade that differs from that of the subsurface drain. This procedure shall be used only if surface water inlets or nearness of the conduit to outlets with fixed water elevations permit satisfactory estimates of hydraulic pressure and flows under design conditions.

All subsurface drains shall have a nominal diameter that equals or exceeds 3 inches. Unless special bedding arrangements are provided, the minimum diameters used in organic soils shall be five inches for plastic tubing and six inches for rigid tile. Rigid tile used in organic soils shall have a minimum length of two feet.

Existing subsurface drains used for outlets.

When an existing subsurface drain is to be used for an outlet, the following shall apply:

Case I – For areas to be drained that are five (5) acres or less.

This will apply principally to small systems and random lines where complete extensive systems are not needed.

An investigation shall be made of the existing subsurface drain to determine that:

1. It is in good physical condition based on observations at the junction point with the new system.
2. It has adequate capacity based on general observations made in the field. A survey or instrument check of the subsurface drain main downstream a distance of 200 to 300 feet from the junction is advisable to determine grade. It will not be necessary to continue this check to the outlet unless observations indicate the advisability of such survey.
3. It has sufficient depth to provide minimum cover for all new lines to be installed.

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

Case II – For areas to be drained in excess of five (5) acres.

The investigation shall include the following:

1. A physical inspection of the existing subsurface drain to determine that it is operative, free from breakdowns, and has an adequate outlet. The physical inspection will constitute observing the physical condition of the subsurface drain for the following conditions:
   a. Breakdowns which are usually accompanied by holes in the land over and along the line.
   b. Fractured tile, such as quartering (fractures on the quarter points, which result in an egg-shape cross-section).
   c. Deposition of soil. If excessive deposition appears, make a further study to determine the cause and correct the situation.
   d. Physical material deterioration that would seriously subject it to failure, due to high absorption rate, soil acidity, or alkalinity, etc.
1. Determine the capacity of the existing tile by checking the grades and sizes in the critical areas, particularly the flat reaches.
2. The existing subsurface drain outlet will be considered adequate if the capacity of the subsurface drain, as determined in Step 2, is greater than 80% of the required capacity, and if the existing tile is not deteriorated because of holes, quartering, roots or submergence of the outlet, except where such damages are repaired, and/or corrected.

If the surface drain is a drain of record or legal drain, all of the information available from the record, shall be used in making the determination as to the adequacy of the tile outlet.

Depth, Spacing, and Location. The depth, spacing, and location of the subsurface drain shall be based on site conditions, including soils, topography, ground water conditions, crops, land use, and outlets.

The minimum depth of cover over subsurface drains in mineral soils shall be 2 feet. This minimum depth shall apply to normal field levels and may exclude sections of line near the outlet or sections laid through minor depressions where the conduit is not subject to damage by frost action or equipment travel.

The minimum depth of cover in organic soils shall be 2.5 feet for normal field levels, as defined above, after initial subsidence. Structural measures shall be installed if it is feasible to control the water table level in organic soils within the optimum range of depths.

The maximum depth of cover for standard duty corrugated plastic tubing shall be 10 feet for trench widths of 2 feet or less (measured at tubing and to 1 foot above top of tubing). Heavy-duty tubing shall be specified for depths greater than 10 feet, trench widths more than 2 feet, or in rocky soils.

Depth of mains shall be designed so that the laterals can be joined to the main with a center-to-center or higher connection. A minimum difference in elevation of 0.3 foot between the flow lines of the main and of the lateral is desirable. Flowline-to-flowline connection is permissible when unavoidable.

For computation of maximum allowable loads on subsurface drains, use the trench and bedding conditions specified and the crushing strength of the kind and class of drain. The design load on the conduit shall be based on a combination of equipment loads and trench loads. Equipment loads are based on the maximum expected wheel loads for the equipment to be used, the minimum height of cover over the conduit, and the trench width. Equipment loads on the conduit are not a concern when the depth of cover exceeds 6 feet. Trench loads are based on the type of backfill over the conduit, the width of the trench, and the unit weight of the backfill material. A safety factor of not less than 1.5 shall be used in computing the maximum allowable depth of cover for a particular type of conduit.

Criteria for depth, spacing, and location are provided in the Drainage and Wet Soil Management, Drainage Recommendations for Indiana Soils, AY-300, Purdue Extension, June 2001 and Chapter 14, Water Management (Drainage), Subchapter C, Subsurface Drainage of the EFH.

Minimum Velocity and Grade. In areas where sedimentation is not a hazard, the minimum grades shall be based on site conditions and a velocity of not less than 0.5 ft/s (feet per second). If a hazard exists, a velocity of not less than 1.4 ft/s shall be used to establish the minimum grades if site conditions permit. Otherwise, provisions shall be made for preventing sedimentation by use of filters or by collecting and periodically removing sediment from installed traps, or by periodically cleaning the lines with high-pressure jetting systems or acceptable cleaning solutions.

Velocities based upon drain material sizes and grades are shown on the applicable nomographs in both the Indiana Drainage Guide and Chapter 14 of the EFH.

Maximum Velocity Without Protection. Excessive flow velocity in the drain may induce piping of soil material into the drain line.

Soil Texture	Velocity, ft/s
Sand and sandy loam	3.5
Silt and silt loam	5.0
Silty clay loam	6.0
Clay and clay loam	7.0
Coarse sand or gravel	9.0

TABLE 1 Maximum Velocities by Soil Texture

Maximum Grade and Protection. On sites where topographic conditions require that drain lines be placed on steep grades and design velocities will be greater than indicated in Table 1 special measures shall be used to protect the conduit or surrounding soil. These measures shall be specified for each job according to the particular conditions of the job site.

The protective measure shall include one or more of the following:

1. Enclose continuous perforated pipe or tubing with fabric-type filter material or properly graded sand and gravel.
2. Use nonperforated continuous tubing, a watertight pipe, or seal joints.
3. Place the conduit in a sand and gravel envelope or blinding with the least erodible soil available.
4. Select rigid butt end pipe or tile with straight, smooth sections and square ends to obtain tight fitting joints.
5. Wrap open joints of the pipe or tile with tar impregnated paper, burlap, or special fabric-type filter material.
6. Install open-air risers for air release or entry.

Iron Ochre Control. If drains are to be installed in sites where iron ochre and manganese dioxide problems are likely to occur, provisions shall be made to provide access for cleaning the lines. Each drain line shall outlet directly into an open ditch and/or shall have entry ports as needed to provide access for cleaning equipment. Drain cleaning provisions shall be installed in such a way that the drains can be cleaned in an upstream or rising grade direction. If possible, drains in ochre-prone areas shall be installed during the dry season when the water table is low and the iron and manganese dioxide is in its insoluble form.

Where possible, in areas where the potential for such problems is high, protection against their development shall be provided by designing an outlet facility to ensure permanent submergence of the drain line.

Protection Against Root Clogging. Problems may occur where it is necessary to place drains in close proximity to perennial vegetation. Roots of water-loving vegatation near subsurface drains may enter and obstruct the flow.

The first consideration is to use nonperforated tubing or closed joints through the root zone area. Where this is not possible, water-loving trees should be removed from a distance of at least 100 feet on each side of the drain. A distance of 50 feet should be maintained from other species of trees except for fruit trees. Orchards can often be drained by drain lines located close to the fruit trees.

Where crops and grasses may cause trouble on drain lines, facilities shall be installed to provide a means for submerging the line to terminate the root growth as desired or to maintain a water table above the drain lines to prevent growth into the system.

Materials. Subsurface drains include conduits of plastic, clay, concrete, bituminized fiber, metal, or other materials of acceptable quality.

The conduit shall meet strength and durability requirements for the site. All conduits shall meet or exceed the minimum requirements of the appropriate specifications published by the American Society for Testing and Materials (ASTM), American Association of State Highway and Transportation Officials (AASHTO), and the American Water Works Association (AWWA).

Foundation. If soft or yielding foundations are encountered, the lines shall be stabilized and protected from settlement by adding gravel or other suitable materials to the trench, by placing the conduit on a treated plank that will not readily decompose or on other rigid supports, or by using long sections of perforated or watertight pipe having adequate strength to ensure satisfactory subsurface drain performance. A flat treated plank shall not be used for corrugated plastic tubing.

Filters and Filter Material. Filters will be used around conduits, as needed, to prevent movement of the surrounding soil material into the conduit. The need for a filter will be determined by the characteristics of the surrounding soil material, site conditions, and the velocity of flow in the conduit. A suitable filter shall be specified if:

1. Local experience indicated a need.
2. Soil materials surrounding the conduit are dispersed clays, silts with a plasticity index less than 7, or fine sands with a plasticity index less than 7.
3. Deep soil cracking is expected, or
4. The method of installation may result in voids between the conduit and backfill material.

If a sand-gravel filter is specified, the filter gradation shall be designed in accordance with National Engineering Handbook (NEH) Part 633, Chapter 26, Gradation Design of Sand and Gravel Filters.

Specified filter material must completely encase the conduit so that all openings are covered with at least 3 inches of filter material except that the top of the conduit and side filter material shall be covered by a sheet of plastic or similar impervious material to reduce the quantity of filter material required.

Artificial fabric or mat-type filter materials shall be used, provided that the effective opening size, strength, durability, and permeability are adequate to prevent soil movement into the drain throughout the expected life of the system.

Envelopes and Envelope Material. Envelopes shall be used around subsurface drains if they are needed for proper bedding of the conduit or to improve the characteristics of flow of ground water into the conduit.

Materials used for envelopes do not need to meet the gradation requirements of filters, but they must not contain materials that will cause an accumulation of sediment in the conduit or that will render the envelope unsuitable for bedding of the conduit.

Envelope materials shall consist of sand-gravel, organic, or similar material. Sand-gravel envelope materials shall all pass a 1.5-inch sieve; not more than 30 percent shall pass a No. 60 sieve; and not more than 5 percent shall pass the No. 200 sieve. ASTM-C-33 fine aggregate for concrete has been satisfactorily used and is readily available.

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

Where organic or other compressible materials are used, they shall be used only around a rigid wall conduit and above the centerline of flexible tubing. All organic or other compressible material shall be of a type that will not readily decompose.

Placement and Bedding. The conduit shall not be placed on exposed rock or stones more than 1.5 inches in diameter for 6 inch or larger tile and stones no more than ¾ inch diameter for tile less than 6 inches. Where such conditions are present the trench must be over-excavated, a minimum of 6 inches and refilled to grade with a suitable bedding material.

The conduit shall be placed on a firm foundation to ensure proper alignment. Prevent runoff and surface water from entering the trench.

If installation will be below a water table or where unstable soils are present, special equipment, installation procedures, or bedding materials may be needed. These special requirements may also be necessary to prevent soil movement into the drain or plugging of the envelope if installation will be made in such materials as quicksand or a silt slurry.

For trench installations of corrugated plastic tubing 8 inches or less in diameter, one of the following bedding methods will be specified:

1. A shaped groove or 90° V-notch in the bottom of the trench for tubing support and alignment.
2. A sand-gravel envelope, at least 3 inches thick, to provide support.
3. Compacted soil bedding material beside

and to 3 inches above the tubing

For trench installations of corrugated plastic tubing larger than 8 inches, the same bedding requirements will be met except that a semi-circular or trapezoidal groove shaped to fit the conduit will be used rather than a V-shaped groove.

For rigid conduits installed in a trench, the same requirements will be met except that a groove or notch is not required.

All trench installations shall be made when the soil profile is in its driest possible condition in order to minimize problems of trench stability, conduit alignment, and soil movement into the drain.

For trench installations where a sand-gravel or compacted bedding is not specified, the conduit shall be covered with selected material containing no hard objects larger than 1.5 inches in diameter. Conduit shall be covered to a minimum of 3 inches above the top of the conduit.

All installations shall meet the minimum requirements of the appropriate ASTM specification.

Auxiliary Structures and Protection. Structures installed in drain lines must not unduly impede the flow of water in the system. Their capacity must be no less than that of the line or lines feeding into or through them. The use of internal couplers for corrugated plastic tubing will be allowed.

If the drain system is to carry surface water flow, the capacity of the surface water inlet shall not be greater than the maximum design flow in the drain line or lines. Covers or trash racks shall be used to ensure that no foreign materials are allowed in the drain lines.

The capacity of a relief well system will be based on the flow from the aquifer, the well spacing, and other site conditions and will be adequate to lower the artesian waterhead to the desired level.

The size of relief wells is generally based on the available materials rather than on hydraulic considerations. Such wells will not be less than 4 inches in diameter.

Junction boxes, manholes, catch basins, and sand traps shall be accessible for maintenance. A clear opening of not less than 2 feet will be provided in either circular or rectangular structures.

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

The drain system shall be protected against velocities exceeding those provided in Table 1 and against turbulence created near outlets, surface inlets, or similar structures. Continuous or closed-joint pipe shall be used in drain lines adjoining the structure where excessive velocities will occur.

Junction boxes shall be installed where three or more lines join or if two lines join at different elevations. In some locations it may be desirable to bury junction boxes. A solid cover shall be used, and the junction box shall have a minimum of 1 ½ feet of soil cover.

If not connected to a structure, the upper end of each subsurface drain line will be capped with a tight-fitting external cap of the same material as the conduit or other durable materials.

Outlet

The outlet must be protected against erosion and undermining of the conduit, entry of tree roots, damaging periods of submergence, and entry of rodents or other animals into the subsurface drain. A continuous section of rigid pipe without open joints or perforations will be used at the outlet end of the line and must discharge above the normal elevation of low flow in the outlet ditch. Standard corrugated plastic tubing is not suitable for the outlet section. Minimize the visual impact of projecting outlets.

Continuously submerged outlets will be permitted for water table control systems if planned and designed according to the Natural Resources Conservation Service (NRCS) Field Office Technical Guide (FOTG) Standard (554) Drainage Water Management.

The outlet pipe and its installation will conform to the NRCS FOTG Standard (620) Underground Outlet.

Watertight conduits strong enough to withstand the expected loads will be used if subsurface drains cross under irrigation canals, ditches, or other structures.

CONSIDERATIONS

When designing subsurface drainage systems, consider the effects the system will have on water quantity and quality.

Effects on quantity to consider include: water budget, base flow and runoff to water uses and users, groundwater recharge, and volume of soil water needed to improve plant growth.

Water quality effects that should be considered include: delivery of sediment, changes in the delivery of dissolved salts, such as nitrates, on downstream water uses and users, changes in delivery of dissolved substances to the aquifer, downstream water temperatures, and the effects on the visual quality of downstream water.

If a concern exists of tile lines picking up polluted water from manure spreading, consider installing tile blocks, stoppable catch basins, or other temporary flow blocking devices.

Consider adding collector mains to minimize the visual impact, potential fear from ice or debris damage, and to facilitate maintenance of the grassed ditch bank.

Consideration shall be given to possible damages above or below the point of discharge that might involve legal actions.

Consideration shall be given to maintaining or enhancing environmental values.

Considerations must be given to preventing adverse impacts to delineated wetlands regulated by State and Federal regulations.

PLANS AND SPECIFICATIONS

Plans and specifications for installing subsurface drains shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

OPERATION AND MAINTENANCE

A maintenance program shall be established by the landowner/user to maintain the functional capacity of the subsurface drain. Items to consider are:

1. Keep inlets, trash guards, collection boxes and structures clean and free of materials that can reduce the flow.

2. Repair all broken or crushed lines to insure proper functioning of the drain.

3. Repair or replace broken or damaged inlets and breathers damaged by livestock or machinery.

4. Periodically, or at a minimum of annually, inspect the outlet conduit and animal guards for proper functioning.

REFERENCES

NEH Part 650, Engineering Field Handbook, Chapter 14, Water Management (Drainage)

NEH Part 633, Soil Engineering, Chapter 26, Gradation Design of Sand and Gravel Filters

Drainage and Wet Soil Management, Drainage Recommendations for Indiana Soils, AY-300, Purdue Extension, June 2001

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

Tree/Shrub Establishment

(Acre)

Code 612

DEFINITION

Establishing woody plants by planting seedlings or cuttings, direct seeding, or natural regeneration.

PURPOSES

- To establish woody plants for forest products.
- To establish wildlife habitat.
- To provide long-term erosion control and improve water quality
- To treat waste.
- To reduction air pollution.
- To sequester carbon.
- To conserve energy.
- To enhance aesthetics.

CONDITIONS WHERE PRACTICE APPLIES

On any areas where woody plants can be grown.

CRITERIA

General Criteria Applicable to All Purposes

- Plans and application of tree/shrub establishment shall comply with all applicable federal, state, and local laws and regulations.
- The species, type of plant material, location, layout and density of the planting shall accomplish the intended purposes.
- Species shall be adapted to the soils, climate and site conditions.
- The planting design shall consider the cultural and management practices likely to occur in the future e.g. thinnings etc.
- Native plant species shall be used whenever possible. Known non-native invasive species shall not be used.
- Woody plants shall be established without compromising the integrity of:
  1. Property Lines
  2. Fences
  3. Utilities
  4. Roads
  5. Legal Drains
  6. Other Easement Areas or Right of Ways

  Where a right-of-way easement exists, written permission from the landowner will be needed.
- Where subsurface drains (tile lines) cross through a tree/shrub planting, and where these drains will remain functional. Sealed conduit shall be installed through the planting and extend a minimum of 50 feet on either side of the planting, or trees/shrubs shall not be planted within 50 feet on either side of the tile line.

Site Preparation/Weed Control for Establishment

1. Eliminate competing vegetation prior to planting or seeding (see Table 1). Before direct seeding or installing weed barrier material heavy grass and/or weed cover shall be eliminated to prevent damage to plants from mice and voles.

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

Indiana NRCS FOTG – September 2002.

2. If fabric weed barrier is used the following shall apply:

- The minimum width of weed barrier material shall be 3 feet wide.
- The weed barrier shall contain UV inhibitor, be permeable to water movement, and have a manufacturer's guarantee not to deteriorate for a minimum of 3 years when exposed to sunlight.
- Weed barrier shall be capable of preventing underlying plant growth.
- Weed barrier shall be installed according to the manufacture specifications.

3. Hay or straw mulch shall not be used for weed and grass control around trees and shrubs.

Planting Dates

- Barerooted stock shall be planted in early spring as soon as the ground thaws until June 1.
- Balled and burlapped or container grown stock shall be planted September 15 to June 1 as local soil and weather conditions permit.
- Direct seeding shall be completed as local soil and weather conditions allow as follows:

  September 15 – December 1 or using stratified seed in the spring after the ground thaws before May 15th except White Oak, Swamp Chestnut Oak, and Chinquapin Oak. These species should be seeded within 10 days after seed drop because they are difficult to store.
- Extension of planting dates is appropriate if approved by the NRCS State Forester.

Planting Stock Size

- Bare rooted stock

Conifers:

Tree Height	Caliper[1]	Minimum Root Length
9"	1/8"	8"
12"	3/16"	10"
15"	3/16"	10"

Hardwoods:

Tree Height	Caliper[1]	Minimum Root Length
8"	3/16"	8"
10'	¼"	10"
12"	¼"	10"

- Balled and Burlapped Stock

Conifers:

Tree Height	Minimum Diameter Ball
18-24"	10"
2-3'	12"
3-5'	14"
5-6'	20"

Hardwoods:

Tree Height	Minimum Diameter Ball	Caliper[1]
5-6'	12"	1/2"
6-8'	14"	3/4"
8-10'	16"	1"

- Container stock (all species)

Container Size	Tree Height	Caliper[1]
1 gallon	2 – 4'	3/8 – 5/8"
3 gallon	2 – 6'	3/8 – 5/8"

[1] Caliper (diameter at ground level) shall be measured at the root collar.

Planting and Storage Guidelines for Woody Stock

- Care and Handling Requirements for Woody Planting Stock

1. Plant material will be protected from desiccation during temporary storage and delivery to the planting site. Stock will be kept in a cool environment out of direct sunlight and wind.
2. If seedling planting is delayed more than 5 days, keep seedlings in shipping container and place in cold storage at 35º to 45º F. If cold storage in not feasible, seedlings will be heeled-in. To heel-in, dig a trench in a shady area, deeper than the root system and spread the roots against the back of the trench. Cover roots completely with soil, tamped to eliminate air pockets. Water as needed to keep the roots moist.
3. Roots of bareroot stock shall be kept moist during planting operations by placing in a water-soil (mud) slurry, peat moss,

sphagnum moss, super-absorbent (e.g. polyacrylamide) slurry or other equivalent material. (Note: Do not soak trees in water for more than 2 hours.)

4. Rooting medium of container and balled and burlapped stock shall be kept moist at all times by periodic watering.

- Planting Requirements for Woody Planting Stock

1. Stock shall not be planted when the soil is frozen or dry. All stock will be planted in a vertical position. Bare root and container stock shall be planted with the root collars approximately at or slightly below the existing ground line. Balled and burlapped stock will be planted with the root collars at or slightly above the existing ground line.
2. Seedlings: The planting trench or hole shall be deep and wide enough to permit roots to spread out and down without J-rooting or L-rooting. If the roots are too long for the planting equipment modestly prune them to the correct length before planting. Never prune back beyond the main root system or more than 25% of the root length. After planting pack soil around each plant firmly to eliminate air pockets.
3. Container trees: Dig a hole slightly larger than the container diameter. Remove plants from containers before placing in the ground and firmly pack soil around roots to eliminate air pockets. Before planting loosen any spiraling roots and prune if needed.
4. Balled and burlapped trees: When handling stock never pick up a tree at the stem or trunk, handle stock at the root ball. Dig a hole 11/2 times as wide as the root ball and about the same depth as the root ball. Remove any rope, wire, or plastic twine from the tree. Pull back burlap around trunk and fold once in the hole. Carefully place the tree in the hole and firmly pack soil around roots to eliminate air pockets. After planting water as needed.

Criteria for Forest Products, Erosion Control, Improve Water Quality, Reduce Air Pollution, And to Sequestrate Carbon

A minimum of 300 trees/acre shall be established using one or a combination of the following methods:

- planting bare root seedlings
- direct seeding
- natural regeneration
- planting container stock

1. Criteria for bare root seedlings

- Planting bare root seedlings is applicable on a wide range of soil types, hydrologic conditions, aspects and slopes. Bare root seedlings can be used in reforestation projects, supplemental plantings and wildlife projects.
- A minimum of 436 trees/acre shall be planted (10 foot by 10-foot spacing or equivalent).

Number of plants required per acre for various spacing

Spacing (feet)	Plants per acre
5 x 5	1742
6 x 6	1210
6 x 8	907
6 x 10	726
7 x 10	622
7 x 7	889
8 x 8	681
9 x 9	538
8 X 10	544
9 x 10	484
10 x 10	436
10 x 12	363
10 x 13	335
12 x 12	302
14 x 14	222
16 x 16	170
18 x 18	134
20 x 20	109

2. Criteria for direct seeding

Seed Inspection

Inspect seed by species selecting at least 10 randomly selected seeds/bushel. Crack or cut seeds open to be sure all seed is filled, moist, normal colored and not damaged by insects. If seed appears to be non-viable increase the seeding rate by the percentage of non-viable seed from the tested seed.

Floating in water can separate walnut seed that has not filled, as the unfilled nuts will float, while the filled nuts will sink. Discard floating walnut seed.

Seed Care, and Storage

Field collected seed shall be placed in porous bags e.g. onion bags, burlap bags, or standard feed sacks and placed in storage no more than 50º F and preferably 35-40º F to prevent heat buildup.

All species except oaks should be kept dry. Oak acorns should be re-hydrated, by soaking in cold water for 4- 24 hours as soon as possible after collection or delivery, maintain moisture content at greater than 25%.

If planting is delayed for more than 2 weeks or planted after February, store seed at 35-40º F in sealed containers as described by species in the "Illinois Direct Seeding Handbook".

Species that need stratification to germinate, shall be stratified as described in the "Illinois Direct Seeding Handbook". Stratification is a pregermination treatment to break seed dormancy. Stratification methods vary by species.

Seeding Rates and Methods

- Shall consist of at least 75%, of a combination of Black Walnut, Oak and/or Hickory species.
- To improve seed germination and to prevent rodent depredation the site (planting rows or entire area) shall be kept bare and free of grass and weed cover before and 2 years after direct seeding is completed.
- Seed shall be sown at 2 times the seed diameter.
- To overcome seed predation double the seeding rate for the first 300 feet on sites adjacent to woodlands.

Seeding rates[1] (minimum):

Seeding Method	**Seeds Per Acre** (heavy seeded species)
Row Planting	3000
Broadcast Planting	4500

[1]See direct seeding rate table on page 5 for seeding rates by species.

Species suitable for direct seeding:

Heavy Seeded Species	**Light Seeded Species**
Black Walnut (*Juglans nigra*)	Ash (*Fraxinus spp.*)
Oak (*Quercus spp.*)	Yellow Poplar or Tulip Tree (*Liriodendron tulipifera*)
Hickory (*Carya spp.*)	Black Cherry (*Prunus serotina*)
Persimmon (*Diospyros virginiana*)	Maple (*Acer spp.*)
Kentucky Coffeetree (*Gymnocladus dioica*)	Basswood (*Tilia americana*)
	Sycamore (*Platanus occidentalis*)
	Hackberry (*Celtis occidentalis*)
	Blackgum (*Nyssa sylvatica*)
	Sweetgum (*Liquidambar styraciflua)*
	Bald Cypress (*Taxodium distichum*)

Row/Seed Spacing for 3000 seeds/acre

Row Spacing (feet)	Seed Spacing (feet)
3	4.8
4	3.6
5	2.9
6	2.4
7	2.0
8	1.8
9	1.6
10	1.5
11	1.3
12	1.2
14	1.0
16	0.9
18	0.8

Direct Seeding Rates Table (Note: walnut and all hickory species are husked)

Common Name	**Scientific Name**	**Range of Seeds/Lb.**	**Ave. Seeds/Lb.**	**Lbs/Ac. For 3000 Seeds/Ac**	**Lbs/Ac. For 4500 Seeds/Ac**
Common Persimmon	*Diospyros virginiana*	665-1764	1200	2.5	4
Black Walnut	*Juglans nigra*	11-100	40	75	112
Hickories (Carya Species)					
Bitternut Hickory	*Carya cordiformis*	125-185	156	20	30
Mockernut Hickory	*Carya tomentosa*	34-113	90	34	51
Pecan	*Carya illinoensis*	151-174	162	19	28.5
Pignut Hickory	*Carya glabra*	175-225	200	15	22.5
Shagbark Hickory	*Carya ovata*	80-150	100	30	45
Shellbark Hickory	*Carya laciniosa*	25-35	30	100	150
Oaks (Quercus species)					
White Oak	*Quercus alba*	70-210	120	25	37.5
Chinquapin Oak	*Quercus muhlenbergii*	263-520	395	8	12
Swamp White Oak	*Quercus bicolor*	90-175	85	35	52.5
Shingle Oak	*Quercus imbricaria*	315-795	415	8	12
Overcup Oak	*Quercus lyrata*	139-154	140	22	33
Bur Oak	*Quercus macrocarpa*	40-145	75	40	60
Swamp Chestnut Oak	*Quercus michauxii*	35-195	85	35	52.5
Cherrybark Oak	*Quercus pagoda*	420-745	580	5	7.5
Pin Oak	*Quercus palustris*	320-540	410	8	12
Northern Red Oak	*Quercus rubra*	75-256	125	24	36
Shumard Oak	*Quercus shumardii*	78-128	100	30	45
Black Oak	*Quercus velutina*	125-400	245	13	20

3. Criteria for Natural Regeneration

Natural regeneration is generally used to supplement direct seeding, container stock, and bare root seedling plantings.

Natural regeneration is not always successful even next to a forested seed wall. A forested seed wall is a site dominated by woody vegetation adjacent to the site. Failure may result from poor site preparation practices, adverse soil conditions or seed predators.

Successful natural regeneration shall establish (>300 stems/acre, including seeded or planted stock if applicable) woody vegetation within 3 years. If natural regeneration has not established woody vegetation after 3 years additional planting will be completed if it is determined that additional natural regeneration will not be sufficient to colonize the site within an acceptable time frame (usually 5 years).

<u>Section 1. (floodplain sites)</u>

Natural regeneration may be considered likely to establish woody vegetation on sites that are frequently flooded (see flooding parameter table) with an upstream floodplain that is dominated by woody vegetation. Flooding frequency can be obtained from the NRCS FOTG, Section II and local observation. If the site is not frequently flooded or if the upstream watershed is not dominated by woody vegetation proceed to Section 2.

<u>Section 2. (non floodplain sites)</u>

This section applies to sites that are not frequently flooded or on flood plain sites that are not downstream from a floodplain dominated by woody vegetation.

In this section natural regeneration may only be considered likely if the site is adjacent to a forested seed wall. A distance of 150 feet for natural regeneration may be used in these instances. If a forested seed wall is not present or is greater than 150 feet from the site natural regeneration is not considered likely.

- **If natural regeneration is not considered likely from Section 1 or 2. Trees and/or shrubs shall planted or seeded.**

Flooding Parameter Table[1]

Flooding Frequency	**Chance of Flooding Each Year**
Frequently	>50%
Occasional	5-50%
Rare	0-5%
Flooding Duration	**Days of Flooding**
Very long	>30
Long	7-30
Brief	2-7
Very Brief	<2

[1]Data can be obtained from the NRCS, FOTG, Section II, Water Features Table. An on-site investigation is recommended to verify flooding or ponding parameters.

4. Criteria for Container Stock

Container stock (potted stock) may be a satisfactory method to establish trees on sites where spring planting of bare root stock is not feasible due to spring and summer flooding or excessive wetness. Container stock may also be appropriate in other situations, e.g. supplemental plantings, windbreaks, environmental plantings etc.

In areas not prone to flooding or ponding, potted stock is generally, not the most efficient or cost effective way to establish woody plants. In most situations bare root seedlings are proven to be more reliable and economical method to establish woody plants.

- **Container stock when natural regeneration is likely**

  If natural regeneration is determined likely from **Criteria for Natural Regeneration** then container stock shall be planted at a minimum rate of 27 plants/acre (40’ x 40’ spacing or equivalent). However, clump planting of trees shall be used when potted stock is likely to fail over large portions of the area due to flooding, wetness, water flow, sand deposition, or debris deposit. The minimum number of trees to plant in a clump shall be 109 trees per acre (20’ x 20’ spacing or equivalent). The minimum clump size shall be ¼ acre unless site conditions suggest otherwise.

- **Container stock when natural regeneration is not likely**

  When natural regeneration is considered not likely from **Criteria for Natural Regeneration** then container stock shall be planted at a minimum rate of 300 plants/acre (12' x 12' foot spacing or equivalent).

Additional Criteria to Reduce Soil Erosion

To control sheet and rill erosion on critical slopes:

- plant trees and shrubs on the contour
- apply mulches as needed, see FOTG (484) Mulching
- seed a cover crop between the planted rows

Cover Crop Seeding Table (using pure live seed)

Species	Seeding Rate Lbs/Ac
Annual Ryegrass	8
Spring Oats	16
Winter Wheat	30

Additional Criteria for Forest Products

Christmas trees
Use a 6' spacing in the rows and a row width to accommodate maintenance equipment. Allow for adequate service roads in the plantation.

Supplemental planting (species enrichment)
Planting additional trees in an area that is already stocked with trees. Supplemental planting is done to improve the stocking and composition of an existing stand. The existing stand is managed for the protection and early development of planted trees.

- Trees shall not be planted in locations where they will be overtopped by other trees left in the stand. Overstory trees shall be killed or removed within 2-5 years after plant establishment. The following table provides a list of species suitable for supplemental planting.

Species Suitable for Supplemental Planting

Scientific Name	Common Name
Fraxinus americana	White Ash
Fraxinus pennsylvanica	Green Ash
Juglans nigra	Black Walnut
Liquidambar styraciflua	Sweetgum
Liriodendron tulipifera	Yellow Poplar or Tulip Tree
Prunus serotina	Black Cherry
Quercus alba	White Oak
Quercus rubra	Red Oak

Fine Hardwood Products

Fine hardwoods are tree species that can be used for furniture, veneer products, etc. In Indiana fine hardwood species include:

Fine Hardwood Species

Scientific Name	Common Name
Acer saccharum	Sugar Maple
Carya illinoensis	Pecan
Juglans nigra	Black Walnut
Liriodendron tulipifera	Yellow Poplar or Tulip Tree
Prunus serotina	Black Cherry
Quercus spp.	Some Oak Species

To promote rapid canopy closure and to produce a forest containing well-formed trees a minimum of 544 trees/acre shall be planted (8' X 10' spacing or equivalent) or established using direct seeding methods.

Criteria to Enhance Aesthetics

Trees or shrubs shall not be planted within 10 feet of fire hydrants, water meters, or utility structures.

Trees and shrubs shall be planted so that the crowns will not infringe on adjoining property unless permission is obtained from the landowner.

Plant Spacing:

- Large trees (mature height greater than 60 feet) shall be planted no closer than 40 feet apart.
- Medium trees (mature height 30-60 feet) shall be planted no closer than 35 feet apart.

- Small trees (mature height less than 30 feet) shall be planted no closer than 25 feet apart.
- Shrubs shall be planted no closer than 3 feet apart.

Use evergreen and/or deciduous species, species with showy flowers, brilliant fall foliage, persistent colorful fruits, and noteworthy growth forms and shapes. Use a mixture of small and/or large trees, and shrubs.

Use curvilinear designs and/or small group plantings to increase visual sight diversity.

CONSIDERATIONS

General

Consider landowners objectives for tree/shrub establishment so that the planned objective for the planting is achievable.

Bare root seedlings should be considered as the standard method to establish trees and shrubs. Planting bare root seedlings has proven to be the most economical and successful method to establish trees and shrubs. However, other methods to establish trees and shrubs may be applicable in some circumstances.

Seed sources for direct seeding and woody planting stock should be locally adapted and come from no more than 200 miles north or south of the planting site.

Consider selecting species from Conservation Tree/Shrub Suitability Groups (CTSG), species to plant, Section II (FOTG). Trees to plant from CTSG's can be viewed at the NRCS Indiana web site.

Monocultures and off site species are discouraged in hardwood reforestation projects.

Consider planting 2-3 rows of conifers along all open plantation edges and planting periodic rows of conifers within large plantings to serve as a woodland border and/or wind barrier.

Consider using a support stake when planting container trees and balled and burlapped stock.

Consider planting a mixture of species (5-10 species) adapted to the site (including conifers, hardwoods, and shrubs) to improve plant diversity.

Seek technical assistance from a professional forester for reforestation or other conservation tree planting projects.

Weed Control

To improve plant growth, consider 2 additional years of chemical weed control after plants are established. Weed control should be performed using narrow bands (2'-3' wide) on each side of a plant row unless the entire site is treated.

Erosion

To control sheet and rill erosion consider the establishing permanent cover between tree rows To treat gully erosion consider closer tree spacing and establishing permanent cover. See FOTG Conservation Cover (327) for additional information.

Forest Products

Fine hardwood species should be mixed with other trees (hardwood and softwood) and shrubs to promote diversity, facilitate thinning operations and encourage straight boles.

Direct Seeding

For direct seedings, if there is not a source of light seeded species within 500 feet of any portion of the site, consider seeding an additional 1000 seeds/acre of heavy or light seeded species.

When using direct seeding consider that spring seeding can reduce rodent and insect damage. Fall seeding can eliminate the need for seed storage.

Natural Regeneration

Sites that are frequently flooded or ponded for long or very long duration may be difficult and unpractical for tree/shrub establishment. Consider using natural regeneration on these sites to establish woody plants and allow the site to revegetate to herbaceous and/or woody plant cover.

Consider that natural regeneration is often likely to occur, but not guaranteed on sites that have a seed source from a forested floodplain system where seeds are deposited in sufficient quantity to establish woody vegetation. On these sites, natural regeneration of light seeded species (e.g.

green ash, silver maple, cottonwood , etc.) may establish large numbers of tree seedlings.

Wildlife

Consider selecting species from FOTG Wildlife Upland Habitat Management (645) and/or FOTG Wetland Wildlife Habitat Management (644) to enhance wildlife benefits.

Shrub species may be direct seeded to provide wildlife habitat. Refer to Direct Seeding of Shrubs, IN-NRCS, Forestry Technical Note No. 16.

Soil Fertility

Consider soil testing to determine pH, Phosphorus (P), and Potassium (K) levels before establishment of woody vegetation. Soil pH should be checked by soil horizons, P and K should be checked in the Ap horizon or upper 8 inches. Species planted should be adapted to soil pH levels at the site. Apply lime only on sites that have been acidified through actions of man e.g. past cropping systems. Consider applying P and K to a medium level for forage production.

PLANS AND SPECIFICATIONS

Plans and specifications for tree/shrub establishment will be prepared for each site in accordance with the criteria for this practice. The plan will include planting dates, site preparation, weed control, plant spacing, species, type of stock used, and planting and storage guidelines.

OPERATION AND MAINTENANCE

Check survivability of planted species after 3 years to insure that at least 300 desirable stems/acre of woody plants are established. If less than 300 stems/acre are established additional planting will be completed if it is determined that additional natural regeneration will not be sufficient to colonize the site within an acceptable time frame (usually 5 years).

Control weed competition during establishment (3 years). Competing weeds, brush, and vines can adversely affect survival, form and rate of tree growth. Additional years of weed control may be needed in some instances e.g. to control johnsongrass, quackgrass, or other hard to control weed species.

Use the following or combination of methods as needed to control weed competition (see Table 1 for specific treatments):

- shallow cultivation
- mowing
- spraying approved herbicides
- cutting woody plants and applying approved pesticides

Shear and shape Christmas trees and correlatively prune hardwood species, as needed depending on species and growth form desired. Refer to FOTG Tree Shrub Pruning (660).

Protect the planting from fire. Plan access roads and firelanes prior to planting. See Indiana Field Office Technical Guide, Section IV for Access Road (560) and Firebreak (394).

Fence if necessary to protect the planting from excessive livestock browsing and trampling damage, refer to FOTG Standards, Use Exclusion (472) and Fence (382).

Protect from disease, rodents, deer, and insects using approved pesticides, hunting, fencing, or other appropriate methods. Additional information can be viewed from the "Illinois Direct Seeding Handbook", Wildlife Damage Management.

SITE PREPARATION TREATMENT ALTERNATIVES, Table 1.

TILLABILITY /SOIL TEXTURE	SOD OR ALFALFA SITES	SMALL GRAIN OR ROW CROP SITES	HEAVY BRUSH & TREE GROWTH	HEAVY WEED GROWTH	BADLY COMPACTED
TILLABLE SITES WITH LOAMY/ CLAYEY SOILS	#1a or #3a	#1b, #2, or #7 depending on need for erosion protection	#5a, #5b, or #5c depending on equipment available	#1a, #3a, or #4 on slopes 0-2% #2, #3b, or #4 on steeper slopes	#6
TILLABLE SITES WITH SANDY SOILS	#1a or #3a	#1b, #2, or #7 depending on need for erosion protection	#5a, #5b, or #5c depending on equipment available	#1a, #3a, or #4 on slopes 0-2% #2, #3b, or #4 on steeper slopes	Normally not applicable
NON-TILLABLE SITES DUE TO STEEPNESS (>18%)	#3b, run strips on contour if practical	Normally not applicable	#5a, #5b, or #5c depending on equipment available	#3b, run strips on contour if practical	Normally not applicable
NON-TILLABLE SITES DUE TO ROCKINESS	#3a or #3b depending on slope	Normally not applicable	#5a, #5b, or #5c depending on equipment available	#3a, #3b, or #4 on slopes 0-2% #3b or #4 on steeper slopes	Normally not applicable

All options for site preparation should also include an approved herbicide application in conjunction with tree planting unless other effective weed control measures are planned and implemented.

1a - Plow entire area and disc down firm in late summer or early fall. If erosion control is a concern establish a temporary cover crop[1] prior to a spring planting.
1b – If needed for erosion control establish a temporary cover crop[1].
2 - Scalp or till in strips 3 to 4 feet wide in spring just before planting. On sloping ground consider running strips on the contour.
3a - Fall burn-down with approved herbicide over entire site. Best window of opportunity is September 1 to October 15 as long as it is applied at least one week before the first killing frost. Also use a pre-emergent herbicide before or during planting to control emerging seedlings.
3b - Fall burn-down in strips 3 to 4 feet wide with approved herbicide. Also use a pre-emergent herbicide before or during planting to control emerging seedlings.
4 - Mow in fall. Use appropriate herbicides in the spring prior to or during planting.
5a - Deaden the undesirable trees and shrubs and let them stand.
5b - Hand clear by cutting and removing undesirable trees and shrubs. Treat stumps with an approved herbicide.
5c - Use heavy equipment to clear and remove undesirable trees and shrubs. Where needed, follow-up with establishment of a temporary cover crop[1] prior to planting.
6 - Subsoil or rip compacted areas. If soil surface is rough use appropriate tillage tool to smooth. Where needed, follow-up with establishment of a temporary cover crop[1] prior to planting. On slopes over 6% subsoil or rip on contour.
7 - No site preparation needed.

[1]Temporary cover can be seeded August 15–September 30 or using a dormant seeding December 10-February 28, using 1/2 bushel/acre of wheat, rye, or spring oats.

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NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

WELL DECOMMISSIONING

(No.)

CODE 351

DEFINITION

The sealing and permanent closure of a water well no longer in use.

PURPOSE

This practice serves to:

- Prevent entry of animals, debris, or other foreign substances into well or well bore hole;
- Eliminate the physical hazard of an open hole to people, animals, and farm machinery;
- Prevent entry of contaminated surface water into well and migration of contaminants into unsaturated (vadose) zone or saturated zone;
- Prevent commingling of chemically or physically different ground waters between separate water bearing zones;
- Eliminate possibility of well being used for any other purpose;
- Conserve yield and hydrostatic head of aquifers;
- Restore, as far as feasible, hydrogeologic conditions that existed before well was constructed.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies to any drilled, dug, driven, bored, or otherwise constructed vertical water well determined to have no further beneficial use, is no longer used, or is in such a state of disrepair that using it to obtain ground water is impractical or a health hazard.

This practice does not apply to water wells that were used for waste disposal.

CRITERIA

Closure options shall be compatible with all applicable Federal, State, and Local requirements.

A water well abandoned prior to January 1, 1988, maybe plugged by the landowner. Water wells abandoned on or after January 1, 1988, must be plugged by an Indiana licensed water well driller.

Data collection. As-built construction documents, maintenance records and other available data for the abandoned water well shall be collected, reviewed and applied toward the development of a well decommissioning plan. Existing conditions shall be documented as defined in Plans and Specifications.

Well preparation. The well shall be cleared of all pumping equipment, valves, pipelines, casings, liners, screens, grease, oil, scum, debris, and other foreign material, to the extent possible.

Disinfection. Before sealing, the entire column of well water shall be brought to an available chlorine concentration of 100 ppm or greater, or other solution specified by local or state requirements. After being agitated in the well water, the chemical solution shall be left for no less than 24 hours to assure complete disinfection.

Plugging materials. Plugging materials do not require disinfection.

Water to be mixed with plugging materials shall be compatible with the material, and shall be of a quality that will not result in contamination of

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

the well or water-bearing zones penetrated by the well.

Placement of plugging materials. Cement and bentonite slurries shall be pumped into place with a grout pipe from the bottom of the well and moving the pipe progressively upward as the well is filled. Pelletized, coarse grade or medium grade crushed bentonite shall be installed in the well by gravity methods in a manner to prevent bridging of the plugging material within the well.

Fill material. Fill material shall be clean and free of organic or other foreign matter. The gradation shall be such that bridging will not occur during placement.

Placement of fill material. When allowed by law, fill materials, such as sand, pea gravel, sand-gravel mix, crushed stone, or agricultural lime can be used to plug a portion of the well. Fill material shall be placed into the well only after the well water has been disinfected. All material shall be placed from the bottom of the well upward by methods that avoid segregation, dilution, or bridging of the material.

For wells greater than 30 inches in diameter, backfill shall be placed and compacted in a manner that minimizes segregation to prevent surface subsidence.

Surface seal. After completion of or during the process of well plugging, the well casing shall be severed at least two (2) feet below the ground surface, and a cement plug larger in diameter than the borehole shall be installed.

The interval between the ground surface and the top of the concrete plug shall be filled with soil material that achieves an in-place hydraulic conductivity equivalent to or less than the surface soil surrounding the well. The ground surface at the sealed well site shall be mounded and graded in a manner that prevents ponding of surface runoff.

Control of elevated formation pressure. If a well penetrates a formation that is under artesian head (confined conditions), or from which a gas is being released under pressure, the grout pressure must be maintained greater than the formation pressure until initial grout set occurs. Procedures for balancing formation pressures during grouting operations shall conform to ASTM D5299 (Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities).

Removal or grouting in place of well casing.

If required, the well casing shall be completely removed from the well by either pulling or overdrilling (overreaming) as explained in ASTM D5299.

If necessary, casing that cannot be removed completely shall be ripped, perforated, or cut off at a depth greater than the maximum potential for frost penetration or any other near surface soil fracturing hazard (such as desiccation), or three feet, whichever is greater. Perforated or ripped casing shall provide sufficient apportioned open area to assure passage of the grout into the space. The casing shall be perforated or ripped throughout the entire length of a confining layer. Casings to be grouted in place shall employ a pressurized grouting procedure that will completely fill and seal the open space around the casing.

Casings to be removed from a collapsing formation shall be grouted concurrently with removal such that the bottom of the casing remains submerged in the grout.

CONSIDERATIONS

This practice may be part of a ground water protection system that includes water and chemical management practices.

To the extent practicable, an abandoned well should be decommissioned in a manner that restores the original hydrogeologic conditions of the well site and does not preclude the use of the site from future land management practices.

All decommissioning procedures, fill and sealing materials need to be selected with due consideration of the site-specific geological, biological, physical, and climatic conditions; the chemical composition of the surrounding soil, rock, and ground water at the well site; and the well's construction practices. Water well drilling records may be available from the IDNR Division of Water.

PLANS AND SPECIFICATIONS

Plans and specifications for decommissioning abandoned water wells shall be consistent with this standard and shall describe the requirements for applying the practice to achieve its intended purposes. A record of the installation of this practice shall be made and shall include the following information:

- Location of the decommissioned well by street address, latitude/longitude, township/range, or other georeference convention, of such precision that it can be readily located in the field, if required, in the future;
- Date of completion of well decommissioning;
- Name of landowner;
- Name, title, and address of person responsible for well decommissioning;
- Total depth of well;
- Age of well, if known;
- Installation method (i.e. drilled, driven, jetted, bucket, dug);
- Length of casing (if known);
- Length of well screen (if known);
- If applicable, length of casing removed or length of casing cut off below ground level;
- Inside diameter of well bore or casing;
- Type of casing material or schedule (e.g., standard weight steel, or PVC Sch-80);
- Static water level measured from ground surface prior to decommissioning;
- Types of materials used for filling and sealing, quantities used, depth intervals for emplacement of each type, and emplacement method used.

Notification requirements. The Indiana Department of Natural Resources, Division of Water shall be notified in writing of a well abandonment within thirty (30) days after plugging is completed. Indiana licensed water well drillers shall report well abandonment on forms provided by the Department.

OPERATION AND MAINTENANCE

The practice site shall be inspected periodically to ensure that the decommissioned well and the adjacent area have not settled or eroded, or are otherwise adversely disturbed. The well site and adjacent ground surfaces shall be maintained in a manner that prevents ponding of surface runoff on the site.

REFERENCES

Listed below are references helpful in planning this practice:

- Indiana Code 25-39
- Rule 312 IAC 13-10
- ASTM D5299, Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities.
- Purdue University Cooperative Extension Service Publication
  - Plugging Abandoned Water Wells: A Landowner's Guide, 1998 (WQ-21)
- Indiana Department of Natural Resources
Division of Water
402 W Washington St Rm W264
Indianapolis, IN 46204
(317) 232-4160
- Indiana Groundwater Association
7829 Prairie View Drive
Indianapolis IN 46256
(317) 596-9760

APPENDIX H — REFERENCES

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APPENDIX I — DISCLAIMER & UPDATES

Disclaimer

This manual establishes criteria and minimum standards and specifications to achieve the goal of maintaining or improving water quality through effective project design, applied planning principles, and the selection of storm water quality measures. The manual also establishes performance standards for storm water quality measures. Although every effort has been made to assess and compile the best available information and technology, the use and application of the information and guidelines contained in this manual is solely the responsibility of the user. It is important to recognize that selecting specific storm water quality measures will require thorough site assessment and design. Many of the measures can be applied and/or installed based on general criteria. However, there are measures contained within this manual that will require selection and design that is based on sound engineering principles. These measures include, but are not limited to, sediment basins, grassed and riprap-lined channels, infiltration trenches, and wetlands. These measures should be evaluated for feasibility and designed by a qualified individual. All structural measures should be designed by a professional engineer.

This manual may not be all inclusive in development of a storm water pollution prevention plan. Users of this manual are encouraged to utilize similar guidance documents, available research, and apply new technology and sound engineering principles to supplement this manual.

It is not the intent of this manual to include all commercial measures or products, but to establish minimum standards manufacturers can use to gage and test their product against.

Use of trade names, brand names, or drawings designating specific products are for reference purposes only and does not constitute an endorsement of products or services by the state of Indiana or any of the cooperating agencies/organizations.

This manual is designed to be nonregulatory and should be used as a reference tool only. The planning principles, design criteria/guidelines, and storm water quality measures are intended to assist plan designers, members of the construction industry, and other land users to meet various regulatory requirements. Appropriate application and implementation of these principles and measures based on individual project conditions will aid in complying with state and local storm water regulations.

Updates

The Indiana Department of Environmental Management's Office of Water Quality recognizes that the field of storm water management and erosion and sediment control is dynamic and technology is continually changing. Therefore, updates of this manual are essential to adequately address the requirements and needs of the construction industry in their endeavor to address these important resource issues. To meet these challenges, the Indiana Department of Environmental Management's Office of Water Quality plans to periodically review and update this manual.

APPENDIX I — DISCLAIMER & UPDATES

The department does not anticipate a significant amount of deviation from the standards described in this manual. However, as local authorities and the construction industry use the storm water quality measures in this manual they may discover new measures, variations of existing measures, or modifications to standards/specifications that are more effective in managing storm water.

In an effort to work cooperatively with the construction industry and to keep the manual up-to-date, the Indiana Department of Environmental Management's Office of Water Quality welcomes comments and suggestions for revisions to this document. All suggestions and recommendations promoting more effective and economical approaches to achieving water quality will be looked upon favorably. Comments and suggestions can be sent to the address below:

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Procedure for Inclusion of Recommendations Received by the Department

Additions and/or corrections will be submitted to a multidisciplinary technical oversight committee. This committee will be responsible for reviewing suggested additions, corrections, and modifications and making recommendations for inclusion in future updates.

Procedures for Requesting Manual Updates

Individuals who would like to be notified of revisions to the Indiana Storm Water Quality Manual should mail contact information (i.e., name, address, city/state/ZIP code, phone number and e-mail address) to IDEM's Office of Water Quality using the above address.