PDHonline Course C188 (3 PDH)

Soil Erosion and Sediment Control

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PROTECTING WATER QUALITY

A field guide to erosion, sediment and stormwater best management practices for development sites in Missouri and Kansas.

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Missouri Department of Natural Resources,
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CHAPTER 2

CAUSES AND EFFECTS OF EROSION AND SEDIMENTATION, HYDROLOGIC CHANGES AND POLLUTION TRANSPORT

The major problem associated with erosion on a construction site is the movement of soil off the site and its consequent pollution of receiving rivers, streams and lakes. In Missouri, 70 to 90 percent of the eroded soil (sediment – see Glossary) that reaches any type of channel is transported to the state's water resources.

Types of Soil Erosion

Soil erosion is a natural process that wears away the earth's surface. Soil particles are detached (eroded), transported (as sediment) and deposited (sedimentation) by wind, water, ice or gravity. On a construction site, the erosion process is accelerated because the soil is left bare and unprotected by vegetation. Water and wind erosion will be described in detail below.

Water Erosion

There are five types of water erosion (shown in Figure 2.1) described below and ranked from least severe to most severe. Splash and sheet erosion can best be prevented by protecting the land surface with vegetation, mulch or erosion control blankets. Sheet, rill and gully erosion can be controlled by keeping runoff velocities slow.

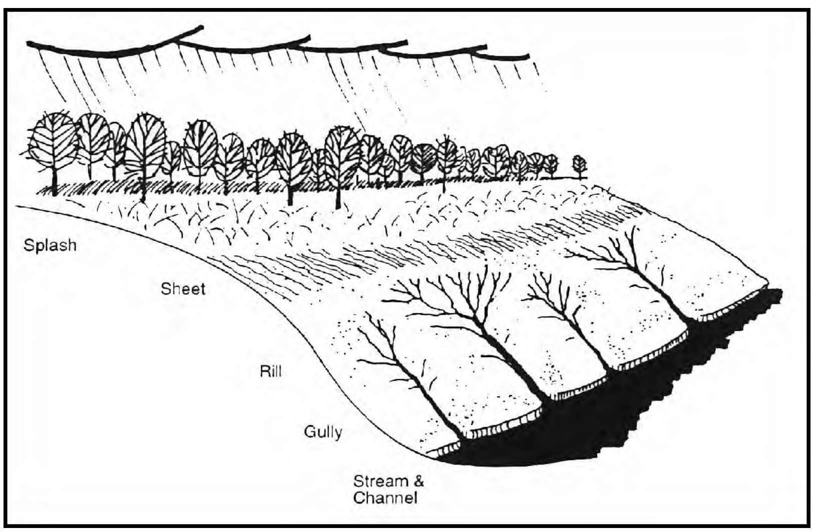


Figure 2.1 The Five Types of Soil Erosion on an Exposed Slope Source: North Carolina DEHNR, 1993

Splash: Splash erosion results from the direct impact of falling drops of rain on soil particles. This impact breaks the bonds between the particles, dislodges them and splashes them into the air. The dislodged soil particles can then be easily transported by the flow of surface water runoff.

Sheet: Sheet erosion is the removal of a thin layer of exposed surface soil by the action of raindrop splash and runoff. The water moves in broad sheets over the land, picks up these particles and carries them along as it flows downhill.

Rill: As the runoff moves down a slope, it cuts small paths or rills. In rill erosion, water flowing through these paths detaches more soil from their sides and bottoms.

Gully: Further down the slope, water tends to concentrate in channels and pick up speed. In gully erosion, soil is removed rapidly by water gushing over the headcut or uphill end of the gully, by concentrated flow scouring the sides and bottom of the gully and by water removing soils that have slumped from the sidewalls of the gully. A nearly vertical headcut allows water falling over the surface to undermine the bank so the gully moves upslope. Large earthmoving equipment is required to reshape or control gullies.

Stream and Channel: Increases in the volume, velocity and time of runoff may cause erosion of the receiving stream or channel banks and bottom.

Wind Erosion

Wind erosion is a serious environmental problem. Suspension, saltation and surface creep are the three types of soil movement that occur during wind erosion (See Figure 2.2).

Suspension: Occurs when very fine dirt and dust particles are lifted into the wind. The particles can be thrown into the air through impact with other particles or by the wind itself. Once in the atmosphere, these particles can be carried very high and be transported over extremely long distances.

Saltation: Fine particles are lifted into the air by the wind and drift horizontally across the surface increasing in velocity as they go. They travel approximately four times longer in distance than in height and when they strike the surface again they either rebound back into the air or knock other particles into the air. This is the major form of soil movement due to wind.

Creep: The large particles that are too heavy to be lifted into the air are moved through a process called surface creep. The particles are rolled across the surface after coming in contact with the soil particles in saltation.

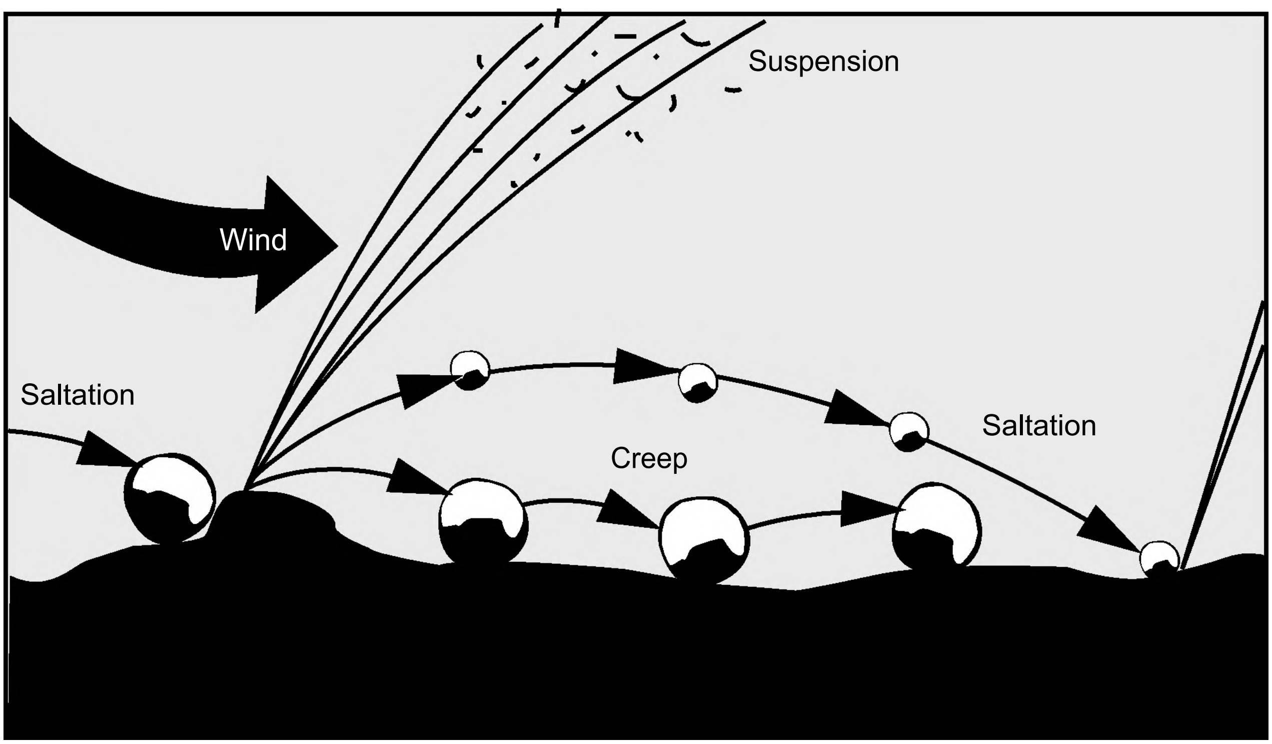


Figure 2.2 Types of Wind Erosion Source: Wind Erosion Research Unit

Factors That Influence Water and Wind Erosion

The potential for a land area to erode is determined by several key factors: climate, rainfall, soil erodibility and the length and steepness of the slope. These factors are interrelated in their effect on the potential for erosion. The variability in terrain and soils makes erosion control unique to each development site.

A site specific soils analysis and the assistance of a registered design professional (see Glossary) can aid in the development of an effective erosion, sediment and stormwater control plan.

Basic Principles of Erosion Control

Keeping soil in place when possible is the first step to erosion control. If the soil must be exposed to stormwater and wind, then it must be contained on the construction site through sediment control measures. Remember erosion controls are preventative and sediment controls are corrective.

The contractor can control erosion and sedimentation most effectively by leaving vegetation intact as long as possible, avoiding removal of streamside vegetation, leaving wetlands in place and phasing in land disturbance to minimize the amount of soil exposed at any one time. Secondly, they can protect whatever soil is exposed from the erosive force of rain, surface water runoff and, in some cases, wind. Eroded soil must be captured and retained on the construction site. In addition, it is important to keep stormwater runoff at low velocities and volumes on-site, and at or below pre-development levels going off-site. Ideally, no sediment is to leave the perimeter of the site. Reasonably, of course, some minimal amount of sediment may leave the site. The following principles will help minimize erosion on the construction site, significantly reduce soil from leaving the site and limit off-site sedimentation that result in water pollution.

Erosion from the splash of a raindrop is caused from the energy of the drop falling from the sky with a specific size and velocity. The most important part of erosion control is to design to protect the soil from the energy of the raindrop by reducing the area of bare soil at any time. Keep as much of the existing vegetation in place as possible. For those areas that were stripped of the existing, protective vegetation, cover the bare soil with erosion control measures and reestablish permanent vegetation as quickly as possible. Remember erosion controls are preventative and sediment controls are remediation.

Retain Existing Vegetation Wherever Feasible

Vegetation is the most effective form of erosion control. Try to integrate the existing vegetation including grass, trees and shrubs into the design to reduce the amount of land disturbance. For those areas where the vegetation must be removed, re-establish vegetative cover as soon as possible to reduce the potential for erosion in these areas. Retain all existing riparian corridor to waterways unless removal is absolutely necessary.

Design the Development to the Site

Reduce the amount of soil cut and fill that could occur over the site. One of the best ways to minimize the risk of erosion and sedimentation problems by construction is to disturb as little of the land as possible. The better the development fits with the topography of the site, the less the grading activity occurs, thereby minimizing the amount and intensity of land disturbance. When development is tailored to the natural topography of the land, less massive earth movement is necessary and erosion potential is greatly reduced. It is also important to avoid disturbance of sensitive areas. You should try to avoid disturbance near wetlands and within the riparian (see Glossary) corridor of perennial streams.

Reduce Surface Runoff by Increasing Infiltration

Vegetation is the most effective form of erosion control. It provides both erosion control and stormwater runoff reduction through infiltration. You can design for increased infiltration by altering the soil texture and subsoil for greater void spaces, which will increase infiltration. Try to integrate the existing vegetation including grass, trees and shrubs into the design to reduce the amount of land disturbance. Retain all existing riparian corridor to waterways unless removal is absolutely necessary. The plants dissipate the energy of the raindrop, reducing the potential for erosion and the root systems increase infiltration and decrease surface runoff.

Protect the Land Surface

Schedule and limit grading activities to minimize bare soil areas and the time of exposure. Consider the use of erosion control blankets, mulch or other erosion control measures when appropriate. Use diversions and perimeter protection to intercept runoff and divert it away from bare soil slopes. Install these practices before clearing and grading or as soon as possible. Stabilize the construction entrance and channels immediately. Establish vegetation on graded areas as quickly as possible or whenever work is interrupted. As stated in the *Missouri State Operating General Permit for Land Disturbance*, "Where soil disturbing activities cease in an area for 14 days or more, the permittee shall construct BMPs to establish interim stabilization."

Keep Runoff Velocities Low

Preserve natural vegetation where possible; mulch and vegetate exposed areas immediately after grading to allow infiltration and slow surface runoff. Use practices that shorten or "break" the slopes to reduce flow volumes and velocities, such as terraces or wattles. Convey stormwater runoff away from steep slopes to stable outlets and detain water in holding ponds before leaving the site.

Capture Sediment on the Site

Sediment traps, basins and barriers are designed to reduce runoff velocity, not filter it; allowing the water to pool and the sediment to settle out. Several sediment traps or barriers located at the border of a graded area are more effective than a single large sediment basin near the site boundary. These practices also reduce the volume and velocity of stormwater runoff.

Schedule Land Grading

The contractor can control erosion and sedimentation most effectively by coordinating the grading sequence and the installation of erosion and sediment control practices. Install key sediment control practices before site grading begins. Schedule or limit grading to small areas. Install the permanent stormwater drains early in the construction and protect all inlets from sedimentation.

Design, Install. Operate and Maintain Practices Properly

Proper design, installation, operation, inspection and maintenance are vital to the success of erosion and sediment control practices. These elements will be covered in Chapter 5. Choosing the wrong practice, improper installation, improper operation and lack of maintenance are the cause of most failures. Failures of installed practices can deliver large amounts of polluted water runoff into streams and lakes. A large structure that fails, such as a detention basin, may be hazardous or damaging to people and property; just as low points in a dike can cause major gullies to form on a fill slope. Ensure the appropriate practice is selected. Also, assign an individual to be responsible for routine checks, operation oversight, repairs and maintenance of erosion, sediment and stormwater control practices.

Figure 2.3 The improperly installed check dam created significant bank erosion. Source: *ABC's of BMP's LLC*

Hydrologic Changes

Land development in urban areas causes drastic changes in the local and watershed hydrology. As land is covered with roads, buildings and parking lots, the amount of rainfall that can infiltrate into the soil is reduced. Figure 2.4 shows the reduction in rainfall infiltration into the soil as paved surface and building cover increases. Table 1.1 shows a range of runoff coefficients for different land uses. The runoff coefficient, or "C" value in the Rational Method of determining runoff, is the percentage of rainfall runoff in the watershed.

This is one reason why construction practices must work hand-in-hand with post-construction runoff controls. It is a relationship that must be well understood. Post-construction controls are designed for the long-term additional runoff from the developed areas to reduce stormwater quantity while improving stormwater quality (See *Missouri Guide to Green Infrastructure: Integrating Water Quality into Municipal Stormwater Management*).

The first line of defense in protecting urban water quality is to assess the entire development site for water quality protection opportunities before ever designing where roads and structures are to be located. The initial stage of site design should work to preserve and enhance the existing features.

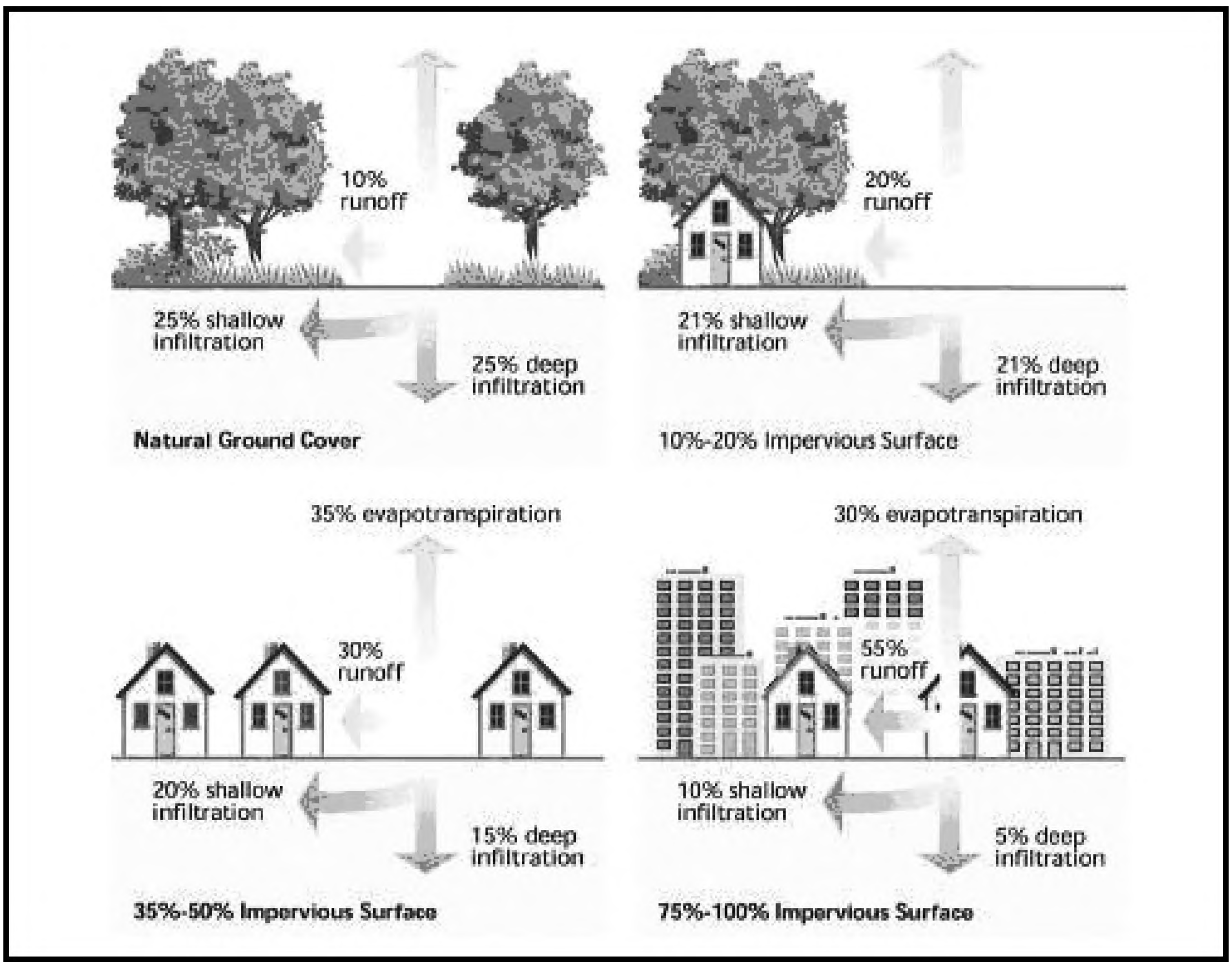


Figure 2.4 Typical changes in runoff flows resulting from paved surfaces
Source: USDA, NRCS, Stream Corridor Restoration, 2001

Land Use	Runoff Coefficient	Land Use	Runoff Coefficient
Business		Lawns	
Downtown	0.70 – 0.90	Sandy soil	0.05 – 0.20
Neighborhood	0.50 – 0.70	Heavy soils	0.13 – 0.35
Residential		Agricultural Lands	
Single Family	0.30 – 0.50	Bare packed soils	0.30 – 0.50
Multiunits, detached	0.40 – 0.60	Cultivated rows	0.30 – 0.60
Multiunits, attached	0.60 – 0.75	Pasture	
Residential, suburban	0.25 – 0.40	Heavy soils	0.15 – 0.45
Apartment	0.50 – 0.70	Sandy soils	0.10 – 0.25
Industrial		Barren slopes	
Light	0.50 – 0.80	Smooth, impervious	0.70 – 0.90
Heavy	0.60 – 0.90	Rough	0.50 – 0.70
Parks, cemeteries	0.10 – 0.25	Woodlands	0.05 – 0.25
Playgrounds	0.20 – 0.35		
Railroad yard	0.20 – 0.40		
Unimproved	0.10 – 0.30		
Drives and walks	0.75 – 0.85		

Table 1.1 Typical Runoff Coefficients as Percentages Source: *Goldman, Erosion and Sediment Control Handbook*, 1986

As land areas are developed, natural drainage patterns are modified when runoff is channeled into road gutters, storm sewers and paved surfaces. These changes concentrate the volume of runoff in drainageways and increase the speed of flow. This results in higher peak discharges and shorter times to reach peak discharge. Figure 2.5 shows typical pre-development and post-development discharge rates versus elapsed time for a site being developed for urban land use. The area under the curves represents the volume discharged. The increased volume and discharge rate shows how the discharge from the site is increased. The rapid rise and fall of runoff is often presented as dangerous flash flood events. Major flooding or soil erosion problems also occur often after an area has been developed.

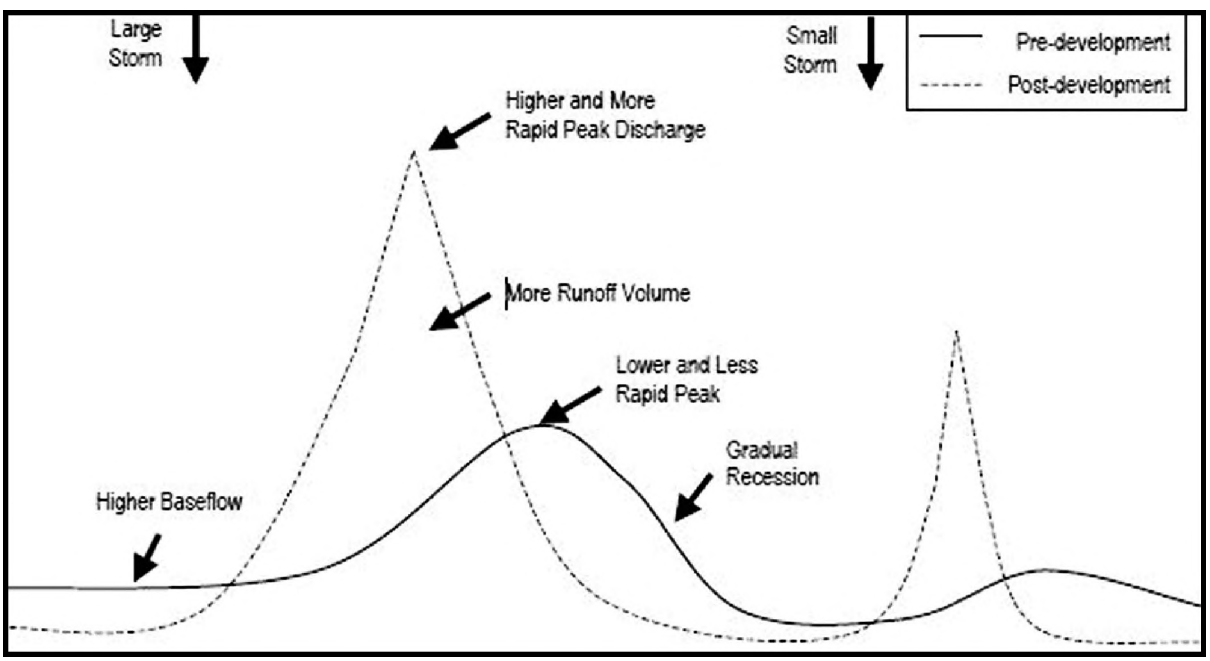


Figure 2.5 Consequences of Development to Urban Streams Source: EPA 841-B-05-004, November, 2005

Another hydrologic effect of urbanization is reduced stream flow during periods of low rainfall. This occurs because paved surfaces do not allow infiltration or retain the water in the soil that would naturally feed the streams. The result is deterioration of the aquatic ecosystem because of high pollutant loadings and low flow during periods of low rainfall.

During periods of high rainfall, the increased discharge rate and downstream flow often cause channel and streambank erosion in the receiving stream. Due to development and increase in impervious surfaces, there is less infiltration of surface water to groundwater and therefore more water arriving in stream channels and at a faster rate. This results in destabilization of streambanks and scouring of stream channels.

Removal of vegetation prior to construction activity is a major contributor to sediment moving off-site and entering nearby streams and lakes. Bare soil is highly vulnerable to erosion. Sediment movement from construction sites can range up to 35-45 tons/acre/year (ASCE and WFF, 1992). Vegetative cover is the most effective control of erosion and sediment loadings.

Pollution Transport

Water pollutants that are commonly transported by stormwater from construction sites in urban settings include sediments, nutrients, petroleum products, chemicals, metals, pesticides, fertilizers and other potentially toxic chemicals (*After the Storm*, EPA Fact Sheet 833-B-03-002, January 2003).

Sediment

Sediment, often incorrectly referred to as silt, (see Appendix A) from soil erosion is made up of soil particles and gravel washed into rivers, lakes and streams. It is the major pollutant in surface waters. Excessive sediment in waterbodies impairs aquatic ecosystems, reduces public water storage and increases drinking water treatment costs. These sediment particles are also a vehicle to transport other pollutants including nutrients, metals, petroleum products and bacteria to surface waters.

Runoff from construction sites is the major source of sediment in urban areas under development. Typical sediment loading rates from construction sites vary from 100 to 200 tons/acre/year (North Carolina DEHNR, 1993). Another major source of sediment is off-site streambank erosion, which is increased by the higher peak runoff flow rates and volumes previously discussed.

Nutrients

Phosphorus and nitrogen are the primary forms of nutrients that can cause water pollution. Lawn fertilizers used to establish and maintain vegetation can be significant sources of phosphorus. Nitrogen comes from fertilizer, too, but is also found in animal wastes, grass clippings and effluent from leaking septic systems.

Phosphorus and nitrogen are sources of food for the algae and bacteria that live in lakes, streams and rivers. Waters polluted with these nutrients develop large numbers of algae and bacteria that use up oxygen, causing fish and other beneficial organisms to die. Nitrates in drinking water are responsible for the “blue baby syndrome” that has caused illness and deaths in infants and have been linked to certain forms of cancer in adults (*Health and Environment Digest*, 1988).

Nutrient pollution can be prevented by composting grass clippings and animal wastes, and repairing leaking septic systems. Nutrient pollution from construction sites can be minimized by applying fertilizer at the rate recommended by a soil test.

Petroleum Products
Petroleum products float on water and are visible. The hydrocarbons in petroleum have a strong characteristic for attaching to sediment particles. Hydrocarbons are known to be toxic to aquatic organisms. Common sources of petroleum products at the construction site are oil storage, fuel facilities, leaks from crankcases and improper disposal of drain oil.

Chemicals
Paints, solvents, sealants, cleaning agents and caulks may be found on construction sites. These chemicals along with chemically composed or treated construction materials may enter the runoff water. Water quality is degraded and removal during water treatment processes may be very expensive.

Metals
Trace metals including lead, zinc, copper, chromium, cadmium and nickel are found on construction sites. In high concentration these metals are toxic to aquatic life. They originate from building materials, vehicle emissions and road sand or salt. Studies have shown that trace metals bioaccumulate in plants and aquatic life in areas where they are contained in sediment.

CHAPTER 4
STORMWATER POLLUTION PREVENTION PLAN OR EROSION AND SEDIMENT CONTROL PLAN

Purpose

A stormwater pollution prevention plan, or SWPPP, is required under all Missouri land disturbance general permits. Some local governments also regulate land disturbance activities and therefore require a SWPPP or what they may refer to as an Erosion and Sediment Control Plan. The purpose of a SWPPP is to identify possible pollutants that may enter stormwater runoff and to identify best management practices, or BMPs, that will minimize or eliminate possible water quality impacts from stormwater runoff. BMPs are physical, structural or managerial practices that prevent or reduce pollution. Best management practices may be used when used singly or in a combination to produce the desired level of results.

A SWPPP must be developed for each construction project subject to regulations and mustbe prepared prior to any land disturbance. The SWPPP will define and schedule the erosion, sediment and good housekeeping control measures to be used on the construction site to prevent or minimize erosion that could occur and keep sediment and other pollutants from exiting the site.

It is stated in the Missouri land disturbance general permit: “...before disturbing earth, or submitting an application, the permittee must develop a SWPPP specific to the land disturbance activities at the site. This plan must be developed before permit coverage can be issued. The permittee must fully implement the provisions of the SWPPP required as a condition of this general permit throughout the term of the land disturbance project.”

In all cases, the permittee and their representative or the contractor(s) responsible for installation, operation and maintenance of the best management practices must have a current copy of the stormwater pollution prevention plan with them when on the project site. In some cases, the permittee may be required to submit a copy of the SWPPP to the Missouri Department of Natural Resources or the local government office. The Missouri Land Disturbance General Permit requires a copy of the stormwater pollution prevention plan be provided to all contractors responsible for installation, operation or maintenance of any best management practice.

Chapter 1 contains information on regulations and permits. The Missouri Department of Natural Resources’ regional office may be contacted for additional information.

The Plan

The stormwater pollution prevention plan should serve as a guide for the selection, location, installation and maintenance of practices to control all anticipated erosion and prevent sediment and other pollutants from leaving the site. A SWPPP is an evolving document that includes text, site maps and forms that are maintained and updated throughout the construction project as the construction site evolves. The requirements for what information must be included in the stormwater pollution prevention planare located within the Missouri land disturbance general permit. If a construction project is within a community that also regulates land disturbance, the contractor will need to include their SWPPP guidelines.

The following items are typical components required in a SWPPP:

- Identification of the person responsible for implementing the SWPPP.
- Physical and environmental description of the site including soils, slopes, vegetation and water resources.
- Description of the construction activity.
- Description of the potential for discharge of sediment and other pollutants from the construction site.
- Narrative, plan sheets and construction details and specifications for erosion, sediment and good housekeeping controls.
- Narrative describing the timing and schedule of installation of erosion, sediment and good housekeeping controls.
- Methods used for final stabilization of all exposed soil areas (should be coordinated with post-construction plans during the initial site design process and again before implementation).
- Information related to conformance with wetland permits (if applicable), the need for environmental review or results of such review, impacts of discharges on endangered or threatened species, and impacts of discharges on historic places or archeological sites.
- Site map showing the following information:
  - Location of areas not to be disturbed.
  - Limits of disturbed area.
  - Location and type of temporary and permanent BMPs.
  - Existing and proposed grades with direction of stormwater flow information before and after construction.
  - Impervious surfaces and soil types.
  - Location of construction phasing.
  - Location of surface waters (e.g., streams, lakes, wetlands) within 0.5 mile of the project.

Developemnts in an area draining to a water body that has been listed on Missouri's impaired water body list (a list required by Section 303(d) of the Clean Water Act), special measures may need to be taken to ensure conformance with the required total maximum daily load, or TMDL, implementation plan. Contractors can determine if the stream might be included in an active TMDL restricted stream by contacting the Missouri Department of Natural Resources or by viewing EPA's approved TMDL list available on the Missouri Department of Natural Resources Web site at www.dnr.mo.gov/env/wpp/waterquality/index.html

Note: After a TMDL has been approved by EPA, the stream will ultimately removed from the impaired water body list. While the water body may still be impaired, it is moved to the TMDL implementation list. The TMDL implementation document then becomes the governing document for addressing the impaired waters.

Understanding the Site Plan and Design

The land site should have desirable natural drainage and soils with good potential for the intended development. Detailed soil surveys and geological investigations should have been completed to assess the suitability for the intended development.

Designate areas on the site map with severe limitations such as floodplains, steep slopes, drainageways, existing bodies of water and unstable soils to be left undisturbed and used as green space to protect water quality. Check local ordinances for limitations of construction in floodplains and near waterways.

Designate natural vegetation and trees to be left undisturbed during construction. Existing areas of grass, shrubs and trees will provide natural erosion and sediment control while enhancing the attractiveness of the project. Check local ordinances for stream corridor setbacks. In some cases, these areas can also be enhanced to help meet water quality protection requirements for both construction and post-construction runoff control.

The site development should been designed so that minimum earth grading and other site preparation is required. Opportunities should be sought to speed up the design approval process by making the design meet the intentions of the municipality's comprehensive or watershed management plan to protect natural resources. Also refer to the numerous resources on contemporary green infrastructure and low impact development designs. Such designs will help the contractor comply with federal, state and local requirements to protect water quality. Much information is available on how these contemporary practices may even minimize your project costs. There are additional resources listed at the end of this chapter.

Rough grading should be completed in phases to keep disturbed areas small and to minimize the amount of time soil will be bare of vegetation. The permit states: "Where soil disturbing activities cease in any area for 14 days or more, the permittee must construct and install BMPs to establish interim stabilization. If the slope of the area is greater than 3:1 or if the slope is greater than 3 percent and greater than 150 feet in length, then the permittee must establish interim stabilization within seven days of ceasing operations on that part of the site."

The SWPPP must present a plan for the installation of best management practices (see Chapter 6 - Practice Installation and Maintenance) to control overland sheet flow, limit erosion and keep sediment and other pollutants on the site.

Topsoil should be stockpiled and stabilized to protect it from erosion and then, following final grading, spread over the areas to be permanently vegetated. Topsoil is rich in organic matter, microorganisms and nutrients for successful vegetation establishment.

The SWPPP must contain a schedule for the installation of best management practices. The installation of best management practices should occure in concert with the development schedule. All best management practices should be in place prior to any disturbance in the area they protect. It is very important to understand the ultimate plan for post-construction runoff to effectively plan, prepare, schedule and coordinate conversion from construction site BMPs to permanent practices. Contractors should schedule the installation of post-construction BMPs after the site is stabilized. There should be no potential for erosion on the site or sediment discharge into the post-construction BMPs.

Provide for operation and maintenance of the permanent, post-construction BMPs after the site is stabilized. If selected, designed, installed and operating properly, these structures will provide stormwater quantity and quality protection after the construction phase of the project is complete.

Developing the SWPPP

Information that Goes in the SWPPP

The SWPPP, or erosion and sediment control plan, has many sections of information in it. The appropriate Missouri Department of Natural Resources general permit for land disturbance and local ordinances should be reviewed to make sure all required information is included in the SWPPP. Table 4.1 provides a checklist of information to be included in the SWPPP. The text column refers to the narrative portion of the document. The site maps are the drawings within the SWPPP. The forms are those documents created as required in the general permit. Each control measure should provide installation and maintenance information, which should be found on the detail sheet. Refer to Chapter 6 for a list of all best management practices.

Table 4.1 SWPPP Checklist of Requirements

Information Required	Sections within the SWPPP			
	Text	Site Map	Forms	Detail Sheet
Site Description (e.g., soils, topography, vegetation)	X			
Discharge Points and Receiving Waters	X	X		
Limits of Disturbance – permitted boundary		X		
Temporary BMP's				
Description of installation and maintenance	X			X
Description of where and why used	X			X
Location		X		
Removal or conversion of controls with site stabilization	X			
Permanent BMPs				
Description of when to install - schedule	X	X		X
Location		X		
Good Housekeeping BMPs	X	X		X
Inspection of all BMPs – when and how	X		X	X
Sequencing and scheduling of work with BMP installation	X	X		
Amending and Updating the SWPPP	X	X	X	
Public Notification	X	X	X	
Contractor Responsibility	X			
Site Stabilization and Termination of Permit Coverage	X			

The following tables also provide questions and goals to set during the design of the construction project. Table 4.2 provides questions on the existing natural resources to be shown on the plan. Table 4.3 provides site development goals to strive for during the design of the construction project.

Table 4.2: Existing Natural Resource Considerations

Natural Resource	Questions	Actions
Wetlands	Are wetlands on-site? Are permits needed (e.g., 404/401 permits) from the Army COE or Missouri Department of Natural Resources?	Show all wetlands on map. Obtain COE/ Missouri Department of Natural Resources permits or documentation before plan approval.
Streams and Floodplains	Are major waterways on the site? Are permits needed from the Army COE or Missouri Department of Natural Resources? Is the site located within the 100- or 500-year flood plain? Is the municipal or county stream buffer (setback) shown? Is the site in a flooding or erosion prone area?	Show major waterways. Obtain COE/ Missouri Department of Natural Resources permits or documentation before plan approval. Obtain local floodplain Development Permit if applicable Show 100- and 500-year flood plains on map. Show stream buffer. Show areas prone to flooding. Show stream bank erosion areas.
Karst	Are sinkholes, springs or seeps located on the site? What is the depth to bedrock?	Local buffer requirements may apply and should be shown. Show sinkholes, springs, seeps and other karst features. Show areas with shallow depth to bedrock.
Existing Topography	What is the existing topography? Are there areas with slopes steeper than 20 percent? What are the site's soil types? What is the existing stormwater drainage area and flow path?	Show existing topography, identify areas with slopes greater than 20 percent. Show site soil type. Show areas with erodible soils. Show gullies, swales, ditches, etc.
Ponds	Are there existing ponds on or adjacent to the property? Does the pond provide recreational benefits? Does the pond provide flood detention benefits? What is the condition of existing ponds (i.e., depth of sediment in pond, bank erosion, invasive plants)?	Show all ponds on map, including any existing detention basins.
Vegetated Cover	Is the site forested? Are grassy/prairie areas on the site?	Show forest and prairie areas. Show large trees (>12" diameter).
Existing Property Use	What is the site's current use? What buildings, structures and other impervious surfaces are present? Are there utilities through the site?	Show existing impervious areas and utilities.
Surrounding Property Use	What is the surrounding property use?	Show property boundary and surrounding property uses.

Table 4.3: Site Development Goals, Questions and Methods

Goal	Questions	Methods (To the Maximum Extent Practicable)
Minimize the Generation of Stormwater Runoff	Can land disturbance be minimized? Can additional green space be preserved? Can proposed development be located in already developed areas?	Limit clearing, grading, and earth disturbance. Use clustered development with open space designs. Use narrower, shorter streets, right-of-way and sidewalks. Allow smaller radii for cul-de-sacs. Reduce parking space requirements. Preserve and protect forested areas, especially areas with large trees. Show tree preservation areas on plans. Allow for shared driveways and parking areas. Provide incentives for site redevelopment.
	Can stormwater safely flow overland to buffer areas (i.e., avoid piping)?	Grade to allow stormwater to sheet flow into buffer or conservation easement areas. Limit use of curb and gutter streets. Use grass channels for street drainage and stormwater conveyance. Allow roof downspouts to flow overland into vegetated cover.
	Can stormwater be captured and infiltrated into the ground?	Rainwater infiltration systems. Examples include rain gardens, dry wells and other landscape infiltration methods. Emphasize managing stormwater at the point of generation.

Determine Limits of Disturbance

The SWPPP must show the limits of disturbance by outlining all areas on the site map where soil will be disturbed or vegetative cover removed. These areas will require erosion and sediment control best management practices. The permitted limits of disturbance must include all areas of soil that will or may be disturbed to complete the construction project. This includes parking and lay down areas, equipment and material staging or storage areas and areas where the contractor will store borrow or fill material. The SWPPP must also outline areas to be left undisturbed and the locations where protective fencing needs to be installed.

Determine Drainage Areas

When beginning the erosion and sediment control design of a construction site, the contractor should first look at the drainage patterns over the site. If there is land uphill of the site with the potential to discharge stormwater onto the contractor's site, the contractor should decide whether or not to accept the discharge and whether or not to design controls for the additional area. If the contractor wishes the design to be solely for the stormwater coming from their permitted site, then you must design diversions for the discharge above your site. These diversions are the very first controls put in place and must be totally stabilized prior to any stormwater being allowed to flow into, through or discharge from them. The diversions must not increase the amount of sediment being discharged from the site.

The SWPPP must separately outline all of the drainage areas that occur on the site. The SWPPP must also identify all of the locations where stormwater is discharged off the development site throughout the entire construction project. Furthermore, the SWPPP must identify the points where the development site will discharge stormwater into natural water ways and identify the distance from the permitted limits of the construction project to the water body.

Select Specific Control Measures

Four areas of concern should be evaluated for each drainage area: soil stabilization (erosion control), runoff control (sediment control), pollution prevention and permanent or post-construction runoff controls. Specific practices to control these areas are described in Chapter 6 - Practice Installation and Maintenance. As control measures are selected, identification symbols and a symbol legend should be placed on the site map. Drawings and specifications for all structural practices and vegetation specifications should be included in the plan including information on proper installation, maintenance and inspection of each control measure. Temporary controls need additional information as to how and when the control is to be removed and the area stabilized.

Soil Stabilization/ Erosion Control

Erosion control devices include vegetation, mulch and compost, rolled products such as blankets, and any other device that is laid on the disturbed soil surface to cover and protect it from raindrop impact and wind erosion. These devices dissipate the energy from the wind and rain so soil particles are not dislodged and moved in the stormwater flow.

Runoff/Sediment Controls

Sediment control devices slow the stormwater flow and/or temporary pool the flow to dissipate the energy of the flowing water. Slowing the flow reduces the water's capacity to transport sediment off the site. Devices effective at reducing flow velocity include silt fences, wattles, inlet protection, sediment traps and ponds, check dams, etc. When using these devices for sediment control on the construction site, contractors should consider the effects that temporary pooling of water, or flooding, may have on areas adjacent to the pooling device.

Pollution Prevention

These devices and practices cover good housekeeping, construction exits, concrete washout, masons area, etc. Good housekeeping includes the management of solid waste (trash and debris), sanitary waste, petroleum-based products and hazardous waste. The SWPPP must identify controls for these possible pollutants on the construction site and their proper inspection and maintenance. The SWPPP also must identify the reportable quantities for petroleum and hazardous waste products and discuss the use of a spill kit on the construction site.

Post-Construction Control Measures

It should be stated whether the control is temporary or permanent within the description of each control device. Structural controls that are permanent must also include information on the operation and maintenance of each control after the construction project is complete and the site is fully stabilized. Maintenance requirements should be explained in the post-construction section with the SWPPP. See Chapter 3 for considerations on permanent stormwater control measures.

These permanent devices are not designed for control of sediment as a post-construction device so they should not be put into permanent use until the site is fully stabilized and there is no threat of erosion or sediment discharge from the site. If devices are to be used during both stages of construction, the device must be fully cleaned of sediment deposits and retrofitted as a post-construction device after the entire site is fully stabilized and there is no hazard of soil erosion occurring. It is very important to coordinate transition from construction site best management practices to post-construction stormwater control measures, especially where newer green infrastructure and low impact development practices will be installed.

Schedule Construction, Stabilization, Inspection and Maintenance Activities

The three main scheduling items required are a construction schedule, a stabilization schedule and an inspection and maintenance schedule. A schedule should also be followed for terminating the project and closing out the permit.

Construction Schedule

The construction schedule must explain in an orderly fashion what will occur from the beginning to the end of the project. This includes both the sequence of the land disturbing activities and the sequence of controls that need to be in place before each of those activities begin. The installation sequence of control practices and structures is a critical factor in controlling erosion and sediment loss on the construction site.

Phasing of site grading is an important element of the schedule. Sediment basins, diversions and conveyance systems, whether temporary or permanent, should be installed either before grading begins or very early in the rough grading process. These practices must be stabilized immediately after they are constructed in order for them to function properly and to prevent structure failure leading to additional erosion and sediment discharge from the site. The sequence of rough grading and temporary stabilization should be indicated for each area to be graded.

The schedule should indicate the control practices to be used if grading is suspended for an extended period of time (seven to 14 days or more depending on slope and distance to waterway). In areas without sediment traps, temporary structures to divert water from cut and fill slopes, temporary seeding with mulch and tackifier or other practices should be used to stabilize the exposed soil surface.

The SWPPP must indicate the planned times and practices for final stabilization, using seed with mulch or using sod. Final stabilization should occur as soon as practicable following final grading.

Stabilization Schedule

The stabilization schedule shows the allowable times for seeding and placing sod to ensure successful vegetation establishment and soil protection (See Temporary and Permanent Seeding). An example is shown in Table 3.1. It should identify the plant species or variety, seeding dates and seeding rates. If alternate species or times are listed, this chart can be used to schedule soil surface protection activities even if the planned construction schedule falls behind. The stabilization schedule should follow closely with the construction schedule. The seeding schedule may also provide for temporary stabilization with annual ryegrass or tackified mulch, if grading is unexpectedly suspended and a permanent seeding cannot be established.

Table 4.1 Example of a Seeding Schedule

Stablization Type	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT
Permanent Seeding with Mulch Turf fescue: 80 lbs/acre	Acceptable (1st half), Optimum (2nd half)	Optimum (1st half), Acceptable (2nd half)	Acceptable			Acceptable (1st half), Optimum (2nd half)	Optimum (1st half), Acceptable (2nd half)	Acceptable
Temporary Seeding with Mulch Annual Ryegrass: 75 lb/acre	Optimum (1st half)	Optimum (1st half)			Acceptable (2nd half)	Acceptable (1st half), Optimum (2nd half)	Optimum (1st half), Acceptable (2nd half)	
Mulch with Tackifier (no seed)				Optimum	Optimum (1st half)			
Fescue or Zoysia Sodding*				Optimum	Optimum (1st half)			

* Ground must be moistened to cool soil temperatures before sod is laid. Use only fresh, good quality sod. Irrigate to soil depth of 4 inches immediately after installation and for the first four weeks, or until sod is well established.

Table Key
- Optimum Seeding Times (dark shading)
- Acceptable Seeding Times (light shading)

Information on seeding rates and types of vegetation is available in Chapter 5 within Table 5.3. You may also contact your county soil and water conservation district for proper vegetation and seeding rates for your area. Remember, you may need to modify the seeding information provided in the SWPPP if the construction schedule changes, therefore changing the time of year you will be installing temporary or permanent vegetation.

Inspection and Maintenance Schedule

The inspection and maintenance schedule is a plan for all temporary and permanent erosion, sediment and stormwater control measures throughout the construction project. This written plan should specify the inspection programs as required in the general permit. It should indicate the work materials and equipment to be used, who is responsible and when inspections and maintenance will be provided.

Inspections are necessary immediately after each phase of construction and storm event, as well as periodic inspection and maintenance to ensure proper functioning of control measures. You should schedule inspections after every rain producing runoff for controls that detain, store or convey stormwater. Work time should be accounted for in the schedule to make immediate repairs to damaged areas and control structures.

Inspection and maintenance should be scheduled for structures such as sediment basins and ponds that require regular cleanout in order to keep them working effectively. Sediment should be removed if it has reached one-half of the designed capacity for sediment storage.

The use of vegetation for erosion control purposes also requires a regularly scheduled maintenance program to repair seeded, sodded or other vegetated areas where the desired degree of stabilization has not been achieved. All seeded areas should be checked for plant emergence and density two to six weeks after planting. Spring plantings should be inspected again during the summer or early fall so reseeding can be performed as necessary during the fall planting season.

The SWPPP inspection and maintenance section should also describe who is responsible for inspections and maintenance of all post-construction BMPs after the land disturbance permit coverage is terminated and the permanent devices are functioning as operational water quantity and quality control devices. After the project is complete, proper stabilization has been achieved according to the general permit and inspection and maintenance of permanent practices have been properly passed off to responsible parties, the project closure should include a termination of coverage of the land disturbance permit using *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 for Missouri Department of Natural Resources (see Chapter 1: Permit Coverage Application Forms and Fees).

Making the SWPPP Work

Even the best SWPPP cannot cover the specifics of each situation that will arise on a construction site during the life of a project. It is the contractor's or site operator's responsibility to make sure the site complies with the goals and intent of the SWPPP at all times. The SWPPP should show the practices to be in place at the start of construction as well as when the site design is at full build out.

The Missouri Department of Natural Resources Land Disturbance general permit states that the permittee must amend and update the SWPPP as appropriate during the term of the land disturbance activity. The SWPPP should record all land disturbance activities from the beginning of construction to the end with the date of occurrence. This would include the installation of best management practices and their removal or conversion into permanent post-construction stormwater control measures. This can be accomplished by a site activity log or notes on the site maps or a combination of both.

The site map should reflect the current activities at the site at any time throughout the construction project. The first records on the site map should include the installation locations and dates of the perimeter BMPs prior to clearing and grading and the location of the trailer, laydown and parking areas. The clearing and grading areas with appropriate dates should then be recorded. As work progresses additional notes should be made for cut areas, fill areas, utility installation, pouring footings and building pad, areas of temporary and final stabilization, etc. The last records on the site map should include the dates when temporary BMPs were removed and those areas stabilized. The last piece of record keeping at the very end of the project is for the permittee to sign and submit *Form H - Request for Termination of a General Permit* Form--MO 780-1409, which will terminate coverage under the general permit. The site must be fully stabilized and all temporary BMPs removed.

The SWPPP is now complete and must kept in the records for three years from the date the Form H was submitted to the Missouri Department of Natural Resources. Submittal of *Form H - Request for Termination of a General Permit* Form--MO 780-1409 is often overlooked, but is an important requirement of the permit. If coverage under the general permit is not terminated, the permittee could continue to be held accountable for activities presumably associated with the permit.

Design Do's and Don'ts

The erosion and sediment control industry is constantly evolving to meet the demands of heightened public awareness of erosion and sediment control issues and regulatory requirements. In the 1970's, ponds were used as sediment basins, geotextiles as silt fence, straw bales as sediment barriers and rock as construction exit pads. Best management practices have evolved significantly since 1992 with the Phase I and II NPDES requirements. There has been extensive research on many of the devices mentioned in this guide, as well as newer products and devices. Designing an up-to-date SWPPP may be challenging because information and technology is constantly changing. Following are three long-standing design practices for which the method of implementation has evolved and where confusion might still exist while planning the use of the BMPs on a construction project.

Straw sales

Straw bales have been proven to be very ineffective for sediment control. They are difficult to install correctly and do not last very long. EPA does not support the use of straw bales as an effective control for sediment on a construction site. They should never be used in concentrated flow channels as check dams or as inlet protection. If used at all they may be effective if installed properly on very flat, small areas where erosion control for the soils is also incorporated over the area.

Silt Fence

Silt fence is another device that should never be used in concentrated flow channels or as an inlet protection device. Remember when using silt fence as a sediment control device, there is the potential during heavy storm events where several feet of stormwater flow may pond behind the device causing flooding of the area. This can create significant damage and cause the device to fail.

Another misuse of silt fence is in the area of perimeter control. One requirement of the construction general permit is to maintain perimeter control. Controls must be in place along the perimeter where stormwater flow exits the permitted area, not the entire perimeter. Silt fence should only be placed along the contour and not up and down slopes, at the top of the hill or any other area that does not directly discharge stormwater flows. When silt fence is not placed directly on the contour, the storm flow will follow the fence as it travels downhill, picking up volume and velocity. This will increase the chances of a blow out at the lowest point due to the increase of concentrated flow to the area. As a SWPPP designer, remember that sediment control devices slow the flow and pond the water and should not cause flooding. Silt fence has the capability to pond two or three feet of water and sediment behind it, and damage from flooding could occur.

Short Circuiting

The discharge point of the pond should not be located near the point where sediment laden stormwater enters the pond. Ponded water is a great energy dissipation device for sediment control (as long as it does not cause flooding). When sediment laden stormwater enters ponded water, the ponded water acts as an energy dissipater and the heavier sediment particles settle out at the entrance to the pond. With additional time the lighter particles in suspension will also settle out to the bottom of the pond. For this reason the discharge point of the pond should not be located near the point where sediment laden stormwater enters the pond. If the inlet is close to the outlet particles may not have sufficient time to settle to the bottom before being discharged, creating a condition called “short circuiting”.

The longer the traveling time for the water between the inflow and outflow the better the pond will function as a control device. If the pond is short circuiting because the inflow and outflow are too close together, it will not function well as a sediment control device. If due to space and topography, there is no way to design for the inflow into the pond to be as far away as possible to the outflow then design for a baffle wall or weir to be built between the two pipes so the entire pond is used as a control device.

Additional Resources

A Builder’s Guide to Low Impact Development –National Association of Home Builders Research Center www.lowimpactdevelopment.org/lid%20articles/Builder_LID.pdf

Examples of Green Infrastructure and Design Approaches – EPA
cfpub.epa.gov/npdes/greeninfrastructure/technology.cfm

Green Infrastructure Center
www.greeninfrastructurecenter.org

Low Impact Development Center
www.lowimpactdevelopment.org/

Low Impact Development for Stormwater Management – Tool base Services
www.toolbase.org/Technology-Inventory/Sitework/low-impact-development

Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices
www.epa.gov/owow/nps/lid/costs07/

Slope Breaks and Surface Roughening

Figure 6.13 Lot benching can shorten slope length and prevent erosion while improving the homeowner's yard. Source: *C. Rahm, NRCS, St. Charles County*

Practice Description

Slope breaks and surface roughening are practices that reshape the ground surface during construction to slow the surface overland stormwater flow and reduce slope length to reduce surface runoff velocities, therefore minimizing soil erosion and sedimentation during construction. Slope breaks and surface roughening are inexpensive ways to provide erosion control during construction prior to establishment of permanent vegetative cover.

Slope breaks, such as diversions or benches, can be used to reduce the length of continuous slopes and reduce erosion (See Diversions).

Recommended Minimum Requirements

Prior to start of construction, the site grading plan should be designed by a qualified professional. The grading plan should show disturbed areas, cuts, fills and finished elevations for all graded areas. The site superintendant and field personnel should refer to plans and specifications throughout the construction process. During construction and reshaping of the topography a slope can be roughened once it has been graded out and prior to reaching final grade and vegetation establishment.

Schedule construction activities so the least amount of area is disturbed at one time.

Slope Breaks

Refer to plan. Table 6.1 provides suggested guidelines for spacing of slope breaks.

Table 6.1 Guidelines for Spacing Slope Breaks

Slope	Spacing (ft.)
33-50%	20
25-33%	40
15-25%	60
10-15%	80
6-10%	120
3-6%	200
< 3%	300

Source: Adapted from North Carolina Field Manual, 1991

Soil Surface Roughening

There are many types of surface roughening techniques such as track walking with a dozer up and down a slope or using a sheep's foot to create dimples in the soil surface. This increases infiltration and slows overland flow.

Surface Runoff

Avoid disturbing natural drainage ways, if possible. At each slope break, intercept runoff and channel it to storm drains or stabilized watercourses. If runoff contains sediment, protect drain inlets with a filter or divert water to a sediment trap or basin according to the site grading plan (See Inlet Protection, Temporary Sediment Trap and Sediment Basin).

Erosion Control

Graded areas should be stabilized with mulch, vegetation, crushed stone, riprap or other measures as soon as work is completed, or if work is interrupted for 14 or more working days. Soil surface roughening is both an erosion and sediment control technique and should not be combined with devices such as erosion control blankets. Blankets should be applied to smooth, fine-graded soil surfaces and will fail if used to cover roughened soil surfaces.

Slopes to be Vegetated

2:1 or flatter; 3:1 or flatter where maintained by tractor or other equipment. Slopes should be roughened during grading operations to retain water, increase infiltration and promote vegetative growth. Slopes should be protected from surface runoff while vegetation is being established (See Diversions, Perimeter Protection).

Borrow and Disposal Areas

As shown on the grading plan; these should be no closer than 100 feet to a streambank or sensitive area (e.g., wetland, spring, cave, sinkhole) in the absence of a specification and should not be placed in an area of stormwater conveyance. Stockpiles should be stabilized if not being used for 14 or more days according to the state and local regulatory requirements. If borrow or disposal locations are off-site, they should also be permitted and have a copy of the permit authorization on-site at all times. This is necessary if the off-site borrow or disposal area is used for this construction project only and disturbs one acre or greater requiring permit coverage.

Outlets for Breaks and Diversions

Stabilized outlets should be provided for runoff from the disturbed area in order to retain sediment on-site.

Construction

Site Preparation

- Erosion and sedimentation control measures should be installed as specified and in the sequence shown on the design plan.
- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Remove and stockpile topsoil (see Topsoiling) if subsoils will not support plant growth.
- Clear and grub areas to be filled and remove trees, vegetation, roots and other debris.
- Check fill to make sure it is does not contain brush, rubbish, oversized rocks or other objectionable material.
- Place fill in layers and compact as specified by the grading plan. Do not use frozen, excessively soft or high organic content material.
- Do not place fill on frozen subgrade, as it may cause an unstable condition due to potential differential settlement when the soil thaws.

Grading

- Construct slope breaks as shown on the grading plan, or in accordance with the recommendations of Table 6.1. A typical slope break is illustrated in Figure 6.14.
- Keep diversions and other water conveyance measures free of sediment during all phases of development.
- Avoid grading and building in areas of seepage. If this cannot be avoided, then install subsurface drains (See Subsurface Drains) in areas where seepage interferes with the grading operations, or where required to improve slope stability or soil bearing capacity.
- Permanently stabilize graded areas immediately after final grading is complete. Use temporary stabilization measures on graded areas when work is to be interrupted or delayed for 14 working days or longer.

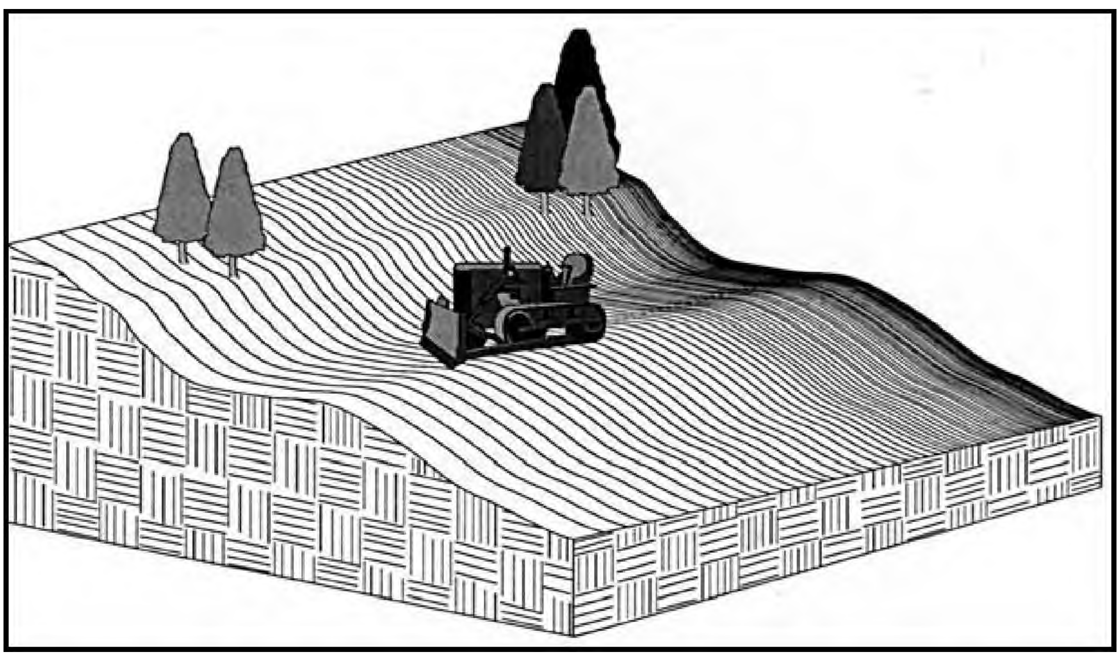


Figure 6.14 Typical Slope Break

Construction Verification
Check all finished grades for conformance with grading plan and correct as necessary.

Figure 6.15 Track walking with a dozer up and down the slope provides horizontal grooves to reduce stormwater flow volumes and velocity therefore reduces potential for erosion of the slope. Source: *ABC's of BMP's, LLC*

Maintenance, Inspection and Removal

- Periodically inspect all graded areas and the related erosion and sedimentation control practices, as required by the construction general permit, especially after heavy rainfalls. Clean sediment out of diversions and other structures as needed. If washouts or breaks occur, repair them immediately.
- Remove this is a temporary device and stabilize the site *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Common Problems and solutions

Problem	Solution
Variations in topography on-site indicate grading plan will be ineffective or unfeasible.	Consult with design professional
Seepage is encountered during construction.	It may be necessary to install drains. Dewatering shall be performed in accordance with regulatory requirements.
Design specifications for seed variety, seeding dates, erosion control materials or timeframes cannot be met.	Substitutions may be required. Unapproved substitutions could result in erosion and lead to failure of erosion control measures.
Prominent rill and gully erosion caused by slope breaks being too far apart.	Construct intermediate slope breaks.
Difficulties achieving proper compaction of fill caused by subgrade being soft, contains oversized rocks or has high organic content.	Undercut and replace unsuitable subgrade soil.
Slope is unstable or has reduced bearing capacity caused by a high water table	Install subsurface drains to lower water table.

Permanent Seeding

Figure 6.25 Permanent vegetation can be used to stabilize many structures, such as this grassed waterway, ensuring that runoff is relatively sediment-free.

Practice Description

Permanent seeding is the establishment of perennial vegetation on disturbed areas for periods longer than 12 months. Permanent vegetation provides economical long-term erosion control and helps prevent sediment from leaving the site. This practice is used when vegetation is desired to permanently stabilize the soil or if future phases of a construction site will remain dormant for a significant period of time after grading. It is necessary to protect earthen structures such as dikes, channels and embankments. Particular care is required to establish a good, thick cover of permanent grass.

Recommended Minimum Requirements

A qualified professional should specify plant materials, seeding rates and times prior to start of construction. The site superintendant and field personnel should refer to plans and specifications throughout the construction process. To ensure germination and growth, prepare seedbed, add soil amendments according to soil tests, mulch all seeded areas and follow the seeding dates.

Seedbed Preparation

For broadcast seeding or drilling, loosen soil to depth of 3-inches. For no till drilling, loosen the soil if it’s compacted. Avoid excessively wet conditions.

Soil Amendments

Incorporate fertilizer and lime (if soil pH is less than 6.0) incorporated 3- to 6-inches into the soil.

Seed Quality
Use certified seed, tested within the past 9 months.

Planting Dates
Coordinate the construction schedule with planting dates appropriate for region and species (See Table 6.5).

Plants
Select from recommended erosion control plants (grass or grass/legume mixtures) as shown in Tables 6.5 and 6.6. Rate of application and seeding dates are shown in Tables 6.4, 6.7 and 6.8.

Mulch
Cover a minimum of 75 percent of the ground surface with approved material (See Mulching).

Inspection
Inspect seeded areas during each weekly inspection. Repair and reseed as necessary.

Installation
During final grading, take soil samples from the top 6-inches in each area to be seeded. Submit sample to a soil testing laboratory for liming and fertilizer recommendations.

Seedbed Preparation
- Seedbed preparation is essential for the seed to germinate and grow.
- For broadcast seeding and drilling, loosen the soil to a depth of approximately 3-inches.
- For no-till drilling, the soil surface does not need to be loosened unless the site has surface compaction.
- Loosen compacted, hard or crusted soil surfaces with a disk, ripper, chisel, harrow or other tillage equipment.
- Avoid preparing the seedbed under excessively wet conditions.

Liming
- Follow the recommendations resulting from the soil test. Apply ground agricultural limestone unless a soil test shows a pH of 6.5 or greater.
- Incorporate lime into the top 3- to 6-inches of soil.
- Do not add lime if the pH is 7.0 or greater.

Fertilizer
Remember: Phosphorus helps roots grow and develop to get the grass plants established. Nitrogen will only be taken up after the seed has germinated and the vegetation is growing. It may wash down stream if applied heavily during seeding.

Note: Fertilizer can be blended to meet exact fertilizer recommendations. Take soil test recommendations to local fertilizer dealer for bulk fertilizer blends. This may be more economical than bagged fertilizer.

For establishment and long-term growth, apply a complete fertilizer at rates recommended by soil tests or as specified in the design plan. In the absence of soil tests, use the following as a guide:

- A typical fertilizer blend for lawn grass mixes: Apply 10-24-18 which represents 10 percent of actual nitrogen – 24 percent of actual phosphorus and 18 percent of actual potassium within the fertilizer compound. If you had 100 pounds of a 10-24-18 blend you would have 10 pounds of actual nitrogen, 24 pounds of actual phosphorus and 18 pounds of actual potassium within the bag.

- A typical application rate of fertilizer for initial establishment of vegetation after seeding is approximately 1 pound of actual nitrogen per 1,000 square feet. With the 10-24-18 fertilizer this would require the application of approximately 435 pounds of this fertilizer mix per acre since there are 43,500 square feet in an acre. This fertilizer would also provide more than 2 pounds of phosphorus per acre.
- Incorporate lime and fertilizer to a depth of 3- to 6-inches by disking or chiseling on slopes of up to 3:1.
- Grade soil to a smooth firm surface to enhance rooting of seedlings and reduce rill erosion.
- Subsequent fertilization with an additional 2 pounds per 1,000 square feet of actual Nitrogen approximately one month after initial seeding will help grass growth after germination to achieve the density of vegetation to prevent or minimize erosion. A typical fertilizer for a second application once vegetation is established would be a 20-10-5 mix at 435 pounds of fertilizer per acre.

Plant Selection

If not specified in the design plan, choose a suitable species of grass or a grass/legume mixture from Tables 6.5 and 6.6 appropriate for the season. Consider site conditions including soils, plant characteristics, region of the state and desired level of maintenance. The species shown are adapted for lawns and erosion control. If there are questions on species selection and how they may be adapted in wildlife habitat or wetland applications, contact your local Natural Resources Conservation Service or Extension office.

Developing a Mixture

A pure stand of grass provides the best erosion control. The advantage of a grass/legume mix is the legume provides nitrogen to the grass and often grows during hotter and drier months when the grass is dormant. Usually one grass and one or two legumes is sufficient in a mixture. More grasses can be mixed together, but may be of little use. Refer to Tables 6.5 and 6.6 for information about each grass and legume to determine the correct species for your site.

Nurse Crops (Temporary or Annual Species)

Nurse crops are temporary grains that have one growing season such as wheat, rye and oats and are sometimes used in a seeding mixture. These annuals can reduce weeds, control erosion and provide protection to young seedlings until the perennial species become established.

Plant nurse crops about 1-inch deep. Most permanent grasses and legumes are sown 1/4 inch deep. Permanent seedings should not be planted deeper than 1/4 to 1/2 inch.

Aesthetic Plantings

A wide variety of native forbs and grasses are available that add diversity and beauty to permanent plantings (e.g., switchgrass as an accent). Contact your local Natural Resources Conservation Service office for species selection and seeding rates.

Planting Dates

If seeding dates are not specified in the design plan or construction has not proceeded according to schedule, use the seeding calendar shown in Table 6.5.

Plant during optimum seeding dates if at all possible. Always use mulch or other erosion control measures to protect the seed and reduce erosion until the vegetation is established. For dormant seeding dates, broadcast seed and immediately roll and cultipack for good soil-to-seed contact.

If unable to seed according to schedule, use temporary seeding until the preferred date for permanent seeding.

Seeding Rates

If seeding rates are not specified in the design plan, use rates in Table 6.8 for grasses alone. Use rates in Table 6.9 for a grass or legume mixture. These rates are based on the poor growing conditions that typically exist on a development site, a need for dense growth and high germination rates.

For best results use certified seed. When using uncertified seed, use the highest recommended seeding rate. Higher seeding rates will not substitute for good seedbed preparation.

- Apply seed uniformly using a cyclone seeder, drop-type spreader, drill, cultipacker seeder or hydroseeder.
- When using a drill seeder, plant rye or other grains about 1-inch deep; plant grasses and legumes no more than 1/2 inch. Calibrate equipment in the field.
- Cover seed by raking, or dragging a chain, brush or mat. Then firm the soil lightly with a roller. Seed can also be covered with hydro-mulched wood fiber and tackifier or a rolled erosion control product.
- Legumes require inoculation with nitrogen-fixing bacteria to ensure good growth. Purchase inoculum from seed dealer and mix with seed prior to planting.

Table 6.5 Planting Dates Optimum and Acceptable* Planting Dates

Species	Seeding Dates Optimum and Acceptable											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Turf Fescue												
Tall Fescue												
Kentucky Bluegrass												
Perennial Ryegrass												
Ryetop												
Reed Canary												
Bermuda - Common												
Bermuda- Hybrid												
Buffalograss[1]												
Zoysia2												
Birdsfood Trefoil												
Common Lespedeza												
Red Clover												
White Clover												
Wheat/Rye[3]												
Oats[3,4]												

[1] Can also be sprigged.

[2] Usually sprigged. Space plugs every 6-, 8- or 12-inches; with 4,000, 2,250 or 1,000 sprigs/1000 ft^2 respectively.

[3] Check with your local Noxious Weed Department before planting.

[4] Nurse crop only.

[5] Provides a quick temporary cover or nurse crop even if planted in the fall.

Table Key

Optimum Seeding Times

* With Mulch Cover - Acceptable Seeding Times

Table 6.6 Plant Characteristics

	Species	Kansas Adaptation	Missouri Adaptation	Maintenance	Fertility Needs	Establish-ment Ease
				L - M - H	L - M - H	P - M - G
6 0 a U) ^0	Perennial ryegrass	E, C, W*	N, S	L	M	M
	Canada wildrye	E, C, W	N, S	M	L	G
	Tall fescue	E, C, W*	N, S	M	L - H	G
	Crested wheatgrass	E, C, W	N	M	L	M - G
	Kentucky bluegrass	E, C, W*	N, S	H	M - H[1]	M - G
	Bromegrass	E, C, W*	N, S	M	M - H[1]	M - G
	Redtop	S1/2 E	N, S	L	L	M
	Reed canary[1]	E, C, W*	N, S	H	L - M[3]	P
C7 o d U) c	Common Bermuda	E, C, W*	S	L	L - M	M
	Hybrid Bermuda	E, C, W*	-	L	L - M	M
	Buffalograss[3]	E, C, W*	N, S	L	L	M
	Blue grama	E, C, W*	N, S	L	L	M
	Zoysia[4]	E, C, W*	-	M	M - H	M
	Sideoats grama	E, C, W*	N, S	M	L	G
	Little bluestem	E, C, W*	N, S	M	L	M
	Big bluestem	E, C, W*	N, S	M	L	M
	Indiangrass	E, C, W*	N, S	M	L	M
	Switchgrass	E, C, W*	N, S	M	L	M
E E d	Birdsfoot trefoil	E, C, W*	N, S	L	M	P - M
	Crownvetch	E, C, W*	N, S	M	M	P - M
	Annual lespedeza[6]	E, C, W*	N, S	M	M	P - M
	Red clover	E, C, W*	N, S	M	M	G
	White clover	E, C, W*	N, S	L	M	M - G
	Alfalfa	E, C, W*	N, S	M	L	P
o R a c o 1! ooo	Wheat	E, C, W*			M	M
	Rye (cereal)	E, C, W*			M	M
	Oats	E, C, W*			M	M

* Adaptation limited to areas that receive additional moisture enhancement by irrigation, subirrigation or overland flow.

[1] Will be high maintenance in lawn – type or low rainfall (<30”) settings.

[2] Adapted to shorelines, wet or frequently flooded areas.

[3] Responds well to fertilizer, but doesn’t necessarily require it.

[4] Usually seeded, by can be sprigged.

[5] Usually sprigged, plugged or sodded.

[6] Legumes alone will not provide adequate erosion protection: use with a grass in a mixture.

[7] Will reseed each year if not mowed until after seed shatter in September.

Table Key

L = low

M = moderate,

H = high.

P = poor,

G = good.

Table 6.7 Species Tolerance for Environmental Conditions

Species		Tolerance: Shade	Drought	Flooding	Traffic	Soil Wetness
[illegible]	Perennial ryegrass	L	L	M	M	M
	Canada wildrye	M	M	L	M	P
	Tall fescue	M	M	M	M	P
	Crested wheatgrass	L	H	M	M	G
	Kentucky bluegrass	L	L	M	H	G
	Bromegrass	L	M	L	H	M
	Redtop	L	L	M	H	G
	Reed canary	L	M	H	H	G
[illegible]	Common Bermuda	L	H	H	H	M
	Hybrid Bermuda	L	H	H	H	M
	Buffalograss	L	H	H	H	G
	Blue grama	L	H	L	M	P
	Zoysia	L	H	M	H	P
	Sideoats grama	L	H	M	H	M
	Little bluestem	L	H	L	L	P
	Big bluestem	L	H	M	L	M
	Indiangrass	L	M	L	M	P
	Switchgrass	L	M	M	M	G
[illegible]	Birdsfoot trefoil	L	H	L	M	G
	Annual lespedeza	L	L	M	L	M
	Red clover	L	L	L	M	P
	White clover	L	L	L	H	M
	Alfalfa	L	L	L	L	P

1 Legumes alone will not provide adequate erosion protection: use with a grass in a mixture.

Table Key

L = Low
M = Moderate
H = High
P = Poor
G = Good

Table 6.8 Seeding Rates

Species		Kansas: Full Seeding Rate[1] lbs./acre (PLS)[2]	Missouri: Full Seeding Rate[1] lbs./acre (PLS)[2]
Cool Season Grasses	Perennial ryegrass	150	150
	Canada wildrye	21	24
	Tall fescue	150	150
	Crested wheatgrass	20	16
	Kentucky bluegrass	120	120
	Bromegrass	100	100
	Redtop	8	8
	Reed canary[1]	40	40
Warm Season Grasses	Common Bermuda	2	4
	Hybrid Bermuda	20 bu./acre	-
	Buffalograss[3]	8 (grain)	8 (grain)
	Blue grama	3	6
	Zoysia[4]	20 bu./acre	-
	Sideoats grama	15	15
	Little bluestem	9	13
	Big bluestem	17	16
	Indiangrass	12.5	16
	Switchgrass	8	9
Legumes[5]	Birdsfoot trefoil	5	10
	Annual lespedeza[6]	14	16
	Red clover	8	12
	White clover	3	4
	Alfalfa	9	9
Companion Crops	Wheat	1 bu./acre	1 bu./acre
	Rye (cereal)	1 bu./acre	1 bu./acre
	Oats	1.5 bu./acre	1.5 bu./acre

[1] Note: Rates based on typical construction site conditions where seedbed is normally less than ideal. Planned future use or specific site conditions may dictate an increase or a decrease in rates. Contact your local Natural Resources Conservation Service office or consulting agronomist for specific seeding rates within your county.

[2] PLS or Pure Live Seed = the amount of seed guaranteed to grow.

[3] Legumes alone will not provide adequate erosion protection: use with a grass in a mixture.

Table 6.9 Example Seeding Mixtures for Critical Area Seeding

Grass - Legume Mixture	Seeding Rate (PLS) *	
	lbs./1000 ft.^{2} ***	lbs./acre
Reed canarygrass / White clover	5 + 0.1	40 + 1
Reed canarygrass / Red clover	5 + 0.25	40 + 2
Tall fescue** / Birdsfoot trefoil	10 + 0.25	80 + 2
Tall fescue** / White clover	10 + 0.1	80 + 1
Tall fescue** / Lespedeza	10 + 0.5	80 + 4
Tall fescue** / Lespedeza / White clover	10 + 0.25 + 0.1	80 + 4 + 1
Tall fescue** / Red clover	10 + 0.25	80 + 2
Tall fescue** / Red clover / White clover	10 + 0.25 + 0.1	80 + 2 + 1
Kentucky bluegrass / White clover	3 + 0.1	25 + 1
Kentucky bluegrass / Red clover	3 + 0.25	25 + 2
Kentucky bluegrass / Birdsfoot trefoil	3 + 0.25	25 + 2
Kentucky bluegrass / Lespedeza	3 + 0.5	25 + 4
Perennial ryegrass / Red Clover	8 + 1	70 + 10
Perennial ryegrass / Birdsfoot trefoil	8 + 0.5	70 + 5
Perennial ryegrass / Lespedeza	8 + 3	70 + 25
Big bluestem / Indiangrass / Switchgrass / Sideoats grama / Western Wheatgrass	-	3.4 + 2.5 + 2 + 3 + 4
Wheat / Rye (as nursery crop)	1.5	60
Oats (as nursery crop)	0.75	30

* PLS or Pure Live Seed = the amount of seed guaranteed to grow. To calculate amount of bulk seed needed: Read seed tag and multiply % purity X % germination = % PLS; then divide lbs of PLS recommended by % PLS. Example: 30 lbs of Reed canary is needed to seed a 1 acre waterway; 90% pure X 90% germination = 81% PLS; 30 lbs PLS / .81 = 37 lbs. bulk seed needed.

** Turf fescue may be substituted for fescue at the same rates.

***Note: Use lbs. / 1,000 ft.^{2} rate to establish dense vegetation for lawns.

Erosion Control

- Mulching or a rolled erosion control product is recommended to conserve moisture, reduce erosion and protect the seed.
- Cover at least 75 percent of the area with approved mulch materials. Crimp, tack or tie down mulch with netting. Mulching is extremely important for successful seeding (See Mulching).

Construction Verification

Check materials and installation for compliance with specifications.

Maintenance and Inspection

- Inspect seeded areas weekly and after rain events. Check for erosion and seed wash out.
- Expect emergence of grasses and legumes within 28 days after seeding, with legumes following grasses.
- Check permanent seeding at each regular weekly inspection. Look for:
  - Germination.
  - Vigorous seedlings.
  - Uniform density with at least 70 percent of the ground surface covered.
  - Uniformity with nurse plants, legumes and grasses well intermixed.
  - Green, not yellow, leaves. Perennials should remain green throughout the summer, at least at the plant bases.

Reseeding

- Inspect seedings for die out for at least a year. Inspect the soil for erosional areas. To repair bare and sparse areas, fill gullies, refertilize, reseed and mulch. Consider no-till planting where possible.
- If stand is inadequate or plant cover is patchy, identify the cause of failure and take corrective action (e.g., choice of plant materials, lime and fertilizer quantities, poor seedbed preparation, lack of topsoil or weather.) If vegetation fails to grow, have the soil tested to determine whether pH is in the correct range or nutrient deficiency is a problem.
- Depending on stand conditions, repair with complete seedbed preparation, then overseed or reseed.
- If it's the wrong time of year to plant desired species, overseed with cereal grain or millets to thicken the stand until timing is right to plant perennials or use temporary seeding.

Fertilization

Satisfactory establishment may require refertilizing the stand in the second growing season.

- Do not fertilize cool season grasses in late May through July.
- Grass that looks yellow may be nitrogen deficient. An application of 500 lbs of 10-10-10 Nitrogen, Phosphorus, and Potassium per acre in early spring will help cool season grasses compete against weeds or grow more successfully.

Remember to convert actual pounds of nutrient needed when determining how many pounds of commercial fertilizer to buy.

- Do not use nitrogen fertilizer if stand contains more than 20 percent legumes.

Mowing

- Consider mowing after plants reach a height of 6- to 8-inches.
- Mow grasses tall, at least 3-inches in height and minimize compaction during mowing process.
- Monitor the late winter and early spring growth of nurse crops to be sure that they do not smother the permanent seeding. Mowing in April may reduce the competitiveness of the nurse crop and open the canopy to allow more sunlight to permanent seedlings that are beginning to grow.
- Vegetation on structural practices such as embankments and grass-lined channels need to be mowed only to prevent woody plants from invading.

Troubleshooting

Consult with design professional if the following occurs:

- Design specifications for seed variety, seeding dates or mulching cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Common Problems and Solutions

Problem	Solution
Poor stand of vegetation caused by inadequate topsoil.	Apply good topsoil with a minimum of 5 percent organic material and reseed.
Poor stand of vegetation caused by inadequate seedbed preparation.	Prepare well-tilled, limed and fertilized seedbed and reseed.
Vegetative stand failures caused by unsuitable choice of plant materials such as seeding Bermuda grass in the north or in the fall.	Select an appropriate species based on plant characteristics in Tables 6.8 and 6.9 and time of seeding.
Perennial vegetation overtaken by nurse crop with too high seeding mixture.	Limit rates to those shown in Table 6.9; eliminate old nurse crop, prepare seedbed and reseed.
Inadequate stand of vegetation caused by seeding at the wrong time of the year.	Consult Table 6.5 and reseed. If timing is not right, use temporary seeding to stabilize soil until preferred seeding dates.
Inadequate stand of vegetation, bare spots or eroded areas caused by inadequate mulching.	Prepare seedbed, reseed, cover seed evenly and tack or tie down mulch, especially on slopes, ridges and in channels (see Mulching).

Hydroseeding

Figure 6.26: Hydroseeding over matt armoring on a steep slope to promote vegetation growth and prevent erosion.
Source: *Florida Erosion and Sediment Control Designer and Reviewer Manual*, June 2007

Hydroseeding is the application of a mixture of water, wood fiber (this could be paper or a 70/30 blend of wood fiber and paper), seed, fertilizer, and a soil stabilizer to temporarily and permanently protect exposed areas of soil from erosion due to wind, rain, and runoff. It is a way to establish grass where grass is the desired cover. This method is most often used in large-scale projects such as highway projects or steep slope areas where straw, sod and blankets are more challenging to use.

Hydroseeding is applied with a mechanical machine. Highway departments often use a boom machine with hoses that can shoot up to 100 feet or more, using soil stabilizers in the seed mix.

For most effective coverage, exposed soil surface should be loose (uncompacted) at time of application. Soil areas can be roughened by rolling the surface with a crimping or punching-type roller or by track walking to increase the soil surface area available for seeding. For best results, cover hydroseed layer (seed with soil stabilizer if used) with a mulch layer to keep applied seeds in place, retain soil moisture, and control soil temperature during seed establishment. The mulch acts as a blanket to protect the seed from wind and erosion.

Fertilizers should be included only when soil tests indicate a lack of adequate nutrients to establish and sustain the selected vegetation. However, there is much debate about whether starter fertilizers should be used at time of seeding. The important factor is to have adequate organic matter in the soil bed so that fertilizing is not necessary. Typically by time the seed germinates and starts to develop a root system, about 25 percent of the fertilizer has leached out or washed away except when one is using a “cross-linked polymer” or so called “water retention polymer”. The other exception is when you are using a growth stimulator that will increase germination therefore allowing more of the starter fertilizer to still be in the soil. There are also other options to using fertilizers, such as guar, biostimulants and other root inoculants.

- The application of a soil binder may be necessary to further stabilize hydraulic mulch and seed to allow for germination and continued growth of vegetation. Soil binders in this case are sold as a tackifier and dust palliative all in one – not soil specific. The soil binder reacts with the soil, binding the mulch, seed, fertilizer, and other additives to the soil, holding it together until vegetation is established. Open weave matting can be applied before hydroseeding areas, especially in areas with steep slopes or sandy conditions, to provide additional structural support, creating a highly erosion-resistant surface to support vegetation establishment. There are also additive products available that have a fibrous material in them to create the same high performance bonding of soil, seed and mulch which is may be cheaper and more efficiently applied through the hydroseeder. See precautions on WCCs under Chemical Application for Turbidity Reduction.

Loading of soil binders and other additives should be done in accordance with machine manufacturer procedures. The hydroseed mix should be applied to the soil as soon as possible following the loading of additives. Otherwise, slurry may become too thick, and the machine could become clogged – wasting time, product and money. Straw, mulch, matting, or jute cover may be applied over the hydroseed application to further promote the vegetation and prevent erosion, but if too thick, the sun, oxygen and water cannot penetrate into the seed/soil.

Installation

- While construction activities are occurring.
- After construction activities are completed.
- Avoid application of hydroseed on existing vegetation, water bodies, sidewalks and roadways. Hydroseeding should not be used in areas where re-disturbance is expected within four to six weeks.
- In a manner that avoids overspray into water bodies, on sidewalks, and on roadways, where the products can end up polluting the water ways.
- Using appropriate hydroseeder equipment.
- Contact the local street department or the state transportation department for more information.

Inspected

- Inspect area at installation to ensure area is properly covered, and receiving waters are properly protected.
- Inspect area after a precipitation event and/or heavy wind for any removal of vegetation, mulch, or other stabilization material.

Maintenance Activities

- Repair coverage and re-apply hydroseed material as needed to maintain maximum protection against erosion.
- If plant seeds fail to germinate, or established plants die, area must be re-seeded. Consult with product distributor or SWPPP preparer for troubleshooting application problems.
- If the desired permanent seeding type is different from the temporary seed, temporary seeding may have to be removed prior to the application of permanent seeding

Common Problems and Solutions

Problem	Solution
In some cases, grass has low germination percentage due to poor contact with soil.	Additives used in hydroseeding can enhance germination and root development, but cautions should be taken to ensure the additives do not make their way to the drainage system.
Hydroseeding application does not cover soil completely and erosion occurs.	Ensure initial application of hydroseeding is done in two directions for proper coverage. Ensure proper products and application rates are used correctly.

Mulch and Hydromulch

Figure 6.27 It takes about two tons per acre of straw mulch to cover at least 75 percent of the ground surface. To prevent erosion and provide the best microclimate for seed establishment, straw mulch should be physically anchored (crimped) or tied down with a tackifier.

Practice Description

Mulch and hydromulch are the application of plant residues such as straw or other suitable materials to the soil surface to reduce erosion. Mulch protects the soil surface from the erosive force of raindrop impact and reduces the velocity of overland flow. It helps seedlings germinate and grow by conserving moisture, protecting against temperature extremes and controlling weeds. Mulch also maintains the infiltration capacity of the soil.

Hydraulic mulch consists of applying a mixture of shredded paper, wood fiber or a hydraulic matrix and a stabilizing emulsion or tackifier with hydroseeding equipment, which temporarily protects exposed soil from erosion by raindrop impact or wind.

Mulch should always be applied to seeded areas to help establish plant cover and protect the seed during establishment.

Recommended Minimum Requirements

Prior to start of construction, mulch requirements should be determined by a qualified professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process..

Material

As specified in the approved site plan. If not specified, select from mulch materials listed in Table 6.10. Base the choice upon soils, slope steepness and length, flow conditions and time of year (See Figure 6.29).

Coverage
At least 75 percent of the soil surface.

Anchoring
Anchor the light materials, such as hay and straw mechanically using a crimping disc or with hydraulic tackifiers or netting. Heavy material mulches such as wood chips will not require anchoring unless on slopes of 4:1 or greater.

Installation
Site Preparation
- Divert runoff water away from areas above the site that will be mulched.
- Remove large dirt clods, stumps, roots and other debris from the construction area.
- Grade area as needed to permit the use of equipment for seeding, mulching and maintenance. Shape area so it is relatively smooth.
- If the area will be seeded, follow seeding specifications in the design plan (See Temporary and Permanent Seeding) and apply mulch immediately after seeding.

Mulching
Spread straw or cereal grain mulch uniformly over the area with a power blower or by hand. No more than 25 percent of the ground surface should be visible after spreading.

Apply at the rates shown in Table 6.10. Use higher rates for steep slopes and other erosive areas.

Anchor straw mulch by one of the following methods:
- Crimp with a weighted, straight, notched disc or a mulch anchoring tool to punch the straw into the soil.
- Tack with a liquid tackifier designed to hold mulch in place. Use suitable spray equipment and follow manufacturer's recommendations.
- Cover with netting, using a degradable natural or synthetic mesh to hold mulch materials in more erosive areas. Anchor the netting according to manufacturer's specifications (See Erosion Control Blankets).
- Anchor wood cellulose mulch with a liquid tackifier.

Figure 6.28 shows straw that that has been crimped with a disc blade as in Figure 6.27. Notice when the blade cuts the straw into the soil to anchor it, some of the straw may become vertical and thereby exposing the soil surface to raindrop impact. The vertical straw acts more like a sediment control and you lose some erosion protection. This can be remedied by increasing the amount of mulch used to 3 or 4 tons per acre if crimping will take place. Table 6.10 provides the application rates of different mulch materials.

Use heavy natural nets without additional mulch, synthetic netting with additional mulch or erosion control mats/blankets to control erosion on steep slopes and in areas needing a higher degree of protection such as waterways, swales and diversion channels. These commercial materials vary greatly in longevity, strength, heaviness and the rate of water flow they can handle.

Install netting and mats/blankets according to manufacturer's specifications making sure materials are properly anchored (See Erosion Control Blankets).

Construction Verification
Check materials and installation for compliance with specifications.

Figure 6.27 Crimping disc. Source: ABCs of BMPs, LLC.


Figure 6.28 Crimped straw. Source: ABCs of BMPs, LLC.

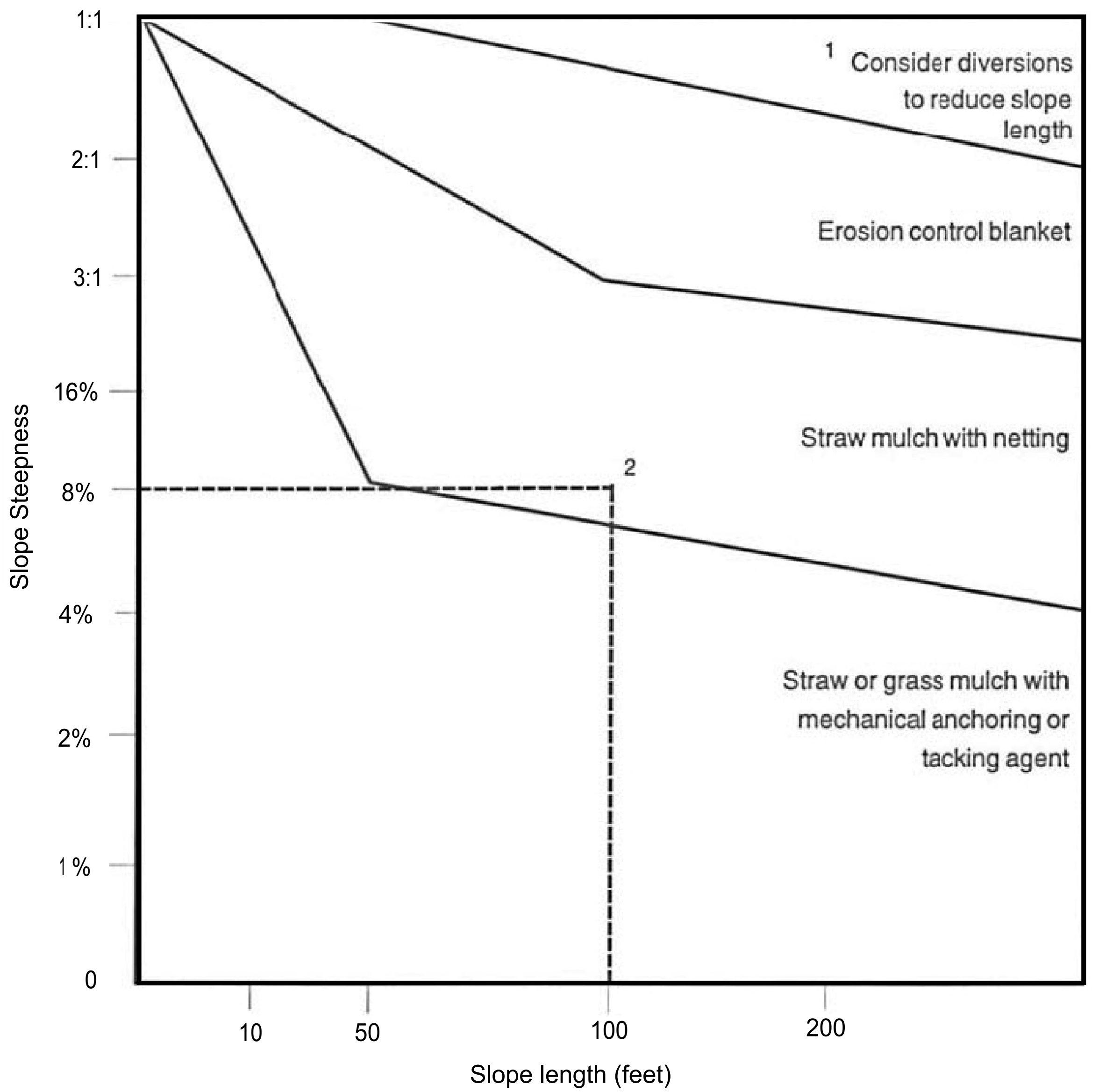
Table 6.10 Typical Mulching Materials and Application Rates

	Rate per Acre	Requirements	Installation Uses	Longevity
Organic Mulches				
Straw	3,000 - 4,500 lb./acre	Dry, unchopped, unweathered; free of weed seeds and rot	Spread by hand or machine, 1.5 to 2.5 inches deep; must be crimped or tacked with vegetative overspray	2 - 4 weeks
Paper, wood fiber, recycled newsprint	2,000 lb./acre	Can use paper on flatter areas, increase percentage of wood fiber as slopes steepen	To be used with hydroseeder, refer to seeding chart for dates to seed	2 - 4 months
Stabilized Fiber Matrix	Refer to manufacturers recommendations - usually 1,500 - 3,000 lb./acre	Typically requires wood fiber mulch to reduce rainfall impact. Requires 24-hour cure time-not used in concentrated flows	To be used on more erodible slopes, molecularly binds soil particles for improved erosion protection, can be used without seed for temporary soil protection	4 - 5 months
Bonded Fiber Matrix	Refer to manufacturers recommendations - 3,000 - 4,000 lb./acre depending on steepness of slope	24-hour cure time, can be used on slopes as steep as 2:1, not used in concentrated flows	Does not require smooth finish grade, can be used in soils with high rock content, can be used with out seed for temporary soil protection	4 - 6 months
Flexible Growth Medium	Refer to manufacturers recommendations - 3,000 - 4,500 lb./acre depending on steepness of slope	No cure time, can be used on slopes steeper than 1:1, not used in concentrated flows without TRM combination	Does not require smooth finish grade, can be used in soils with high rock content, molecularly binds soil particles, equivalent to short term erosion control blankets in many cases	up to 1 year
Wood Chips	10-20 Tons	Air dry, add nitrogen fertilizer	Apply with blower...	6 - 9 months
Bark	35 cubic yds.	Air dry...	Apply with...	6 - 9 months
Tackifiers				
Mulch tackifiers	Rates vary-refer to manufacturers specifications	Powders, liquids, crystals, etc.; most are water soluble	Mix with organic mulches to hold together, heavier rates required for steeper slopes	1 - 3 months
Straw Tackifiers	750 lb./acre	Recycled newsprint with tackifier	Spray overtop of vegetative mulching to hold together for extended time.	1 - 3 months
Soil Binders				
Chemical and Biodegradable products: Many Trade Names	Follow manufacturers specifications	Use for temporary and longer term stabilization of non-vegetative soils	Some may be harmful to plant growth, check manufacturers recommendations for seeding limitations	30 days to 6 months depending upon rate

Source: ASP, Enterprises, 2009

* See Temporary Erosion Control Blanket section for nettings and mats.

**Enlist the assistance of a Certified Professional in Erosion and Sediment Control for specific recommendations.



For slopes steeper than 1:1, consider building a diversion above slope to divert water.

Example: An 8 percent slope 100’ long requires a straw mulch with netting.

* Recommendations for specific sites may vary depending upon local conditions.

Figure 6.29 General mulch recommendations to protect from splash and sheet flow. Source: Adapted from *Minnesota Protecting Water Quality in Urban Areas, 1991*

Troubleshooting

Consult with a qualified design professional if any of the following occur:

- Variations in topography on-site indicate the mulching materials will not function as intended; changes in the plan may be needed.
- Design specifications for mulching materials or seeding requirements cannot be met; substitution may be required. Unapproved substitutions could result in erosion or seeding failure.

Maintenance and Inspection

Inspect all mulched areas on a weekly basis and after rainstorms for erosion and damage to the mulch. Repair promptly and restore to original condition. Continue inspections until vegetation is well established. Keep mower height high if plastic netting is used to prevent netting from wrapping around mower blades or shaft.

Common Problems and Solutions

Problem	Solution
Erosion, washout and poor plant establishment.	Check for proper topsoil, repair eroded surface, reseed, remulch and anchor mulch.
Mulch is lost to wind or stormwater runoff.	Reapply mulch and anchor by crimping, netting or tacking.
Mulch not anchored in channel; resulting in channel bottom eroding	Repair damage, replace mulch and anchor or install appropriate turf reinforcement mat channel liner.
Mulch deteriorates before plant establishment.	Check for proper topsoil, reapply mulch, do not hydromulch in winter.

Erosion Control Blankets

Figure 6.30 Follow manufacturer's recommendations to successfully install erosion control blankets or matting. The manufacturer of this high velocity blanket called for stapling every two feet and a check slot wherever two sections were joined. This blanket was used to protect soil and establish grass in a waterway on the August Busch Memorial Conservation Area

Practice Description

Erosion control blankets are used to aid in controlling erosion on critical areas by providing a protective cover made of straw, jute, wood or other plant fibers; plastic, nylon, paper or cotton. This practice is best used on slopes and channels where the erosion hazard is high and plant growth is likely to be slow to provide adequate protective cover for the seed and soil until germination. Erosion control blankets are typically used as an alternative to mulching but are also used to provide structural erosion protection.

Some important factors in the choice of a blanket are: soil conditions, steepness of slope, length of slope, type and duration of protection required to establish desired vegetation, and probable sheer stress. (See Compost for compost blanket considerations.)

Recommended Minimum Requirements

Prior to the start of construction, the application of erosion control blankets should be designed by a qualified professional and plans and specifications should be available to field personnel. The field inspector should verify that installation is in accordance with the plans and specifications.

Numerous products designed to control erosion are available. Product installation procedures for manufactured erosion control blanket products should always be available from the manufacturer. Tables 6.11 and 6.12 list some of the more common temporary and permanent products available.

Table 6.11 Types of Temporary Erosion Control Blankets

ULTRA SHORT-TERM - Typical three month functional longevity						
Type	**Product Description**	**Material Composition**	**Slope Applications***		**Channel Applications***	**Minimum**
			Maximum Gradient	**C Factor**[2, 5]	**Max. Shear Stress**[3, 4, 6]	**Tensile Strength**[1]
1.A	Mulch Control Nets	A photodegradable synthetic mesh or woven biodegradable natural fiber netting.	5:1 (H:V)	< 0.1 @ 5:1	0.25 lb./ft.^{2} (12 Pa)	5 lb./ft. (0.073 kN/m)
1.B	Netless Rolled Erosion Control Blankets	Natural or polymer fibers mechanically interlocked or chemically adhered together to form a RECP.	4:1 (H:V)	< 0.1 @ 4:1	0.5 lb./ft.^{2} (24 Pa)	5 lb./ft (0.073 kN/m)
1.C	Single-net Erosion Control Blankets and Open Weave Textiles	Processed degradable natural or polymer fibers mechanically bound together by a single rapidly degrading, synthetic or natural fiber netting or an open weave textile of processed rapidly degrading natural or polymer yarns or twines woven into a continuous matrix.	3:1 (H:V)	< 0.15 @ 3:1	1.5 lb./ft.^{2} (72 Pa)	50 lb./ft. (0.73 kN/m)
1.D	Double-net Erosion Control Blankets	Processed degradable natural and/or polymer fibers mechanically bound together between two rapidly degrading, synthetic or natural fiber nettings.	2:1 (H:V)	< 0.2 @ 2:1	1.75 lb./ft.^{2} (84 Pa)	75 lb./ft. (1.09 kN/m)
SHORT-TERM - Typical 12 month functional longevity						
2.A	Mulch Control Nets	A photodegradable synthetic mesh or woven biodegradable natural fiber netting.	5:1 (H:V)	< 0.1 @ 5:1	0.25 lb./ft.^{2} (12 Pa)	5 lb./ft. (0.073 kN/m)
2.B	Netless Rolled Erosion Control Blankets	Natural and/or polymer fibers mechanically interlocked or chemically adhered together to form a RECP.	4:1 (H:V)	< 0.1 @ 4:1	0.5 lb./ft.^{2} (24 Pa)	5 lb./ft. (0.073 kN/m)
2.C	Single-net Erosion Control Blankets and Open Weave Textiles	An erosion control blanket composed of processed degradable natural or polymer fibers mechanically bound together by a single degradable synthetic or natural fiber netting to form a continuous matrix or an open weave textile composed of processed degradable natural or polymer yarns or twines woven into a continuous matrix.	3:1 (H:V)	< 0.15 @ 3:1	1.5 lb./ft.^{2} (72 Pa)	50 lb./ft. (0.73 kN/m)
2.D	Double-net Erosion Control Blankets	Processed degradable natural and/or polymer fibers mechanically bound together between two degradable, synthetic or natural fiber nettings.	2:1 (H:V)	< 0.2 @ 2:1	1.75 lb./ft.^{2} (84 Pa)	75 lb./ft. (1.09 kN/m)

EXTENDED-TERM - Typical 24 month functional longevity.						
3.A	Mulch Control Nets	A slow degrading synthetic mesh or woven natural fiber netting.	5:1 (H:V)	< 0.10 @ 5:1	0.25 lb./ft.[2] (12 Pa)	25 lb./ft. (0.36 kN/m)
3.B	Erosion Control Blankets & Open Weave Textiles	An erosion control blanket composed of processed slow degrading natural or polymer fibers mechanically bound together between two slow degrading synthetic or natural fiber nettings to form a continuous matrix or an open weave textile composed of processed slow degrading natural or polymer yarns or twines woven into a continuous matrix.	1.5:1 (H:V)	< 0.25 @ 1.5:1	2.00 lb./ft.[2] (96 Pa)	100 lb./ft. (1.45 kN/m)
LONG-TERM - Typical 36 month functional longevity.						
4	Erosion Control Blankets and Open Weave Textiles	An erosion control blanket composed of processed slow degrading natural or polymer fibers mechanically bound together between two slow degrading synthetic or natural fiber nettings to form a continuous matrix or an open weave textile composed of processed slow degrading natural or polymer yarns or twines woven into a continuous matrix.	1:1 (H:V)	< 0.25 @ 1:1	2.25 lb./ft.[2] (108 Pa)	125 lb./ft. (1.82 kN/m)

Source: *Erosion Control Technology Council.*

* "C" factor and shear stress for Types 1.A., 2.A. and 3.A mulch control nettings must be obtained with netting used in conjunction with pre-applied mulch material.

[1] Minimum Average Roll Values, Machine direction using ECTC Mod. ASTM D 5035.

[2] "C" Factor calculated as ratio of soil loss from RECP protected slope (tested at specified or greater gradient, h:v) to ratio of soil loss from unprotected (control) plot in large-scale testing.

[3] Required minimum shear stress RECP (unvegetated) can sustain without physical damage or excess erosion (> 12.7 mm (0.5 in) soil loss) during a 30-minute flow event in large-scale testing.

[4] The permissible shear stress levels established for each performance category are based on historical experience with products characterized by Manning's roughness coeffecients in the range of 0.01 - 0.05.

[5] Acceptable large-scale test methods may include ASTM D6459,or other independent testing deemed acceptable by the engineer.

[6] Per the engineers discretion. Recommended acceptable large-scale testing protocol may include ASTM D6460, or other independent testing deemed acceptable by the engineer.

TABLE 6.12 Types of Temporary Erosion Control Blankets - For applications where vegetation alone will not sustain expected flow conditionsor provide sufficient long-term erosion protection.

PERMANENT[1] - All categories of TRMs must have a minimum thickness of 0.25 inches (6.35 mm) per ASTM D 6525 and U.V. stability of 80 percent per ASTM D 4355 (500 hours exposure).					
Type	**Product Description**	**Material Composition**	**Slope Applications**	**Channel Applications***	**Minimum**
			Maximum Gradient	**Max. Shear Stress**[4, 6]	**Tensile Strength**[2, 3]
5.A	Turf Reinforcement Mat	Turf Reinforcement Mat – A rolled erosion control product composed of non-degradable synthetic fibers, filaments, nets, wire mesh or other elements, processed into a permanent, three-dimensional matrix of sufficient thickness. Mats that may be supplemented with degradable components, are designed to impart immediate erosion protection, enhance vegetation establishment and provide long-term functionality by permanently reinforcing vegetation during and after maturation. Note: Mats are typically used in hydraulic applications, such as high flow ditches and channels, steep slopes, stream banks, and shorelines, where erosive forces may exceed the limits of natural, unreinforced vegetation or in areas where limited vegetation establishment is anticipated.	0.5:1 (H:V)	6.0 lbs/ft^2 (288 Pa)	125 lbs/ft (1.82 kN/m)
5.B	Turf Reinforcement Mat		0.5:1 (H:V)	8.0 lbs/ft^2 (384 Pa)	150 lbs/ft (2.19 kN/m)
5.C	Turf Reinforcement Mat		0.5:1 (H:V)	10.0 lbs/ft^2 (480 Pa)	175 lbs/ft (2.55 kN/m)

Source: *Erosion Control Technology Council.*

[1] For mats containing degradable components, all property values must be obtained on the non-degradable portion of the matting alone.

[2] Minimum Average Roll Values, machine direction only for tensile strength determination using ASTM D6818 (Supercedes Mod. ASTM D5035 for RECPs)

[3] Field conditions with high loading or high survivability requirements may warrant the use of a mat with a tensile strength of 44 kN/m (3,000 lb./ft.) or greater.

[4] Required minimum shear stress mat (fully vegetated) can sustain without physical damage or excess erosion (> 12.7 mm (0.5 in.) soil loss) during a 30-minute flow event in large scale testing.

[5] Acceptable large-scale testing protocol may include ASTM D6460, or other independent testing deemed acceptable by the engineer.

Construction
Site Preparation

- Grade the site in accordance with the approved design to a smooth and uniform surface, free of debris.
- Add and incorporate topsoil where needed.
- Make sure seed bed is firm yet friable.
- Seed and fertilize as shown on the design plan.

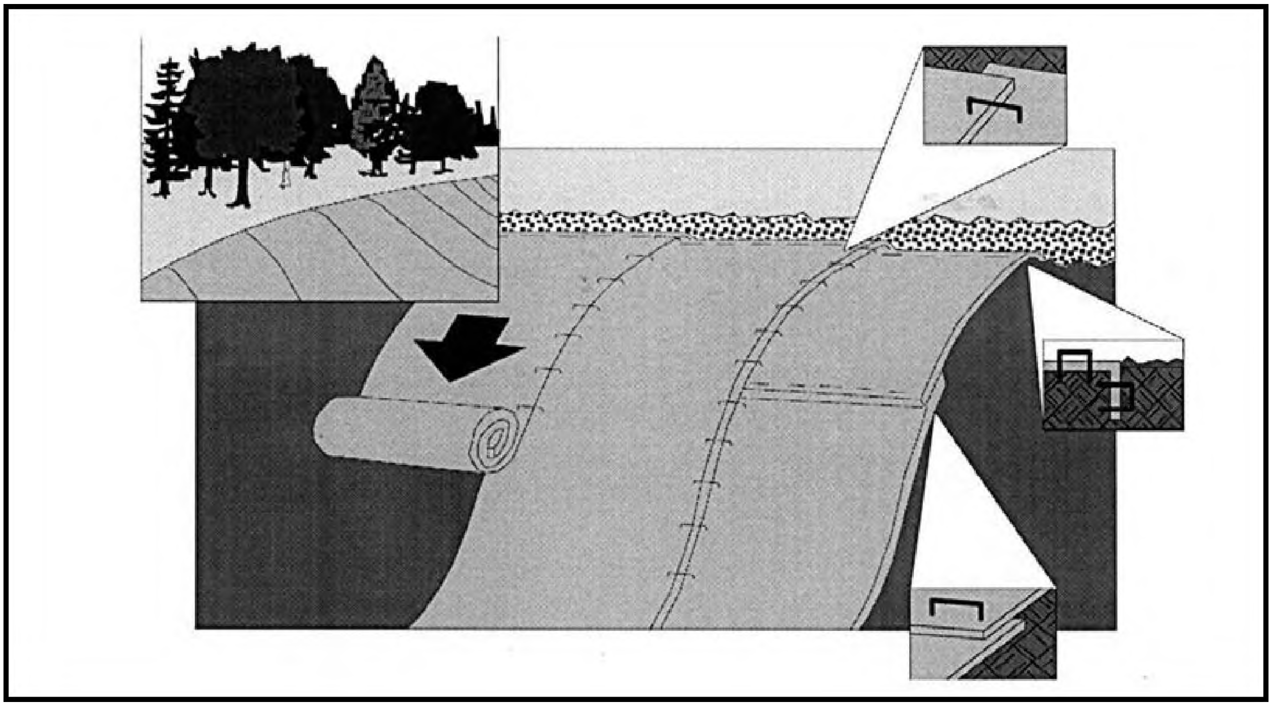


Figure 6.31 Typical installation of erosion control blankets on a slope - Consult manufacturer for recommendations on proper installation of staple patterns, overlap and keying edges.

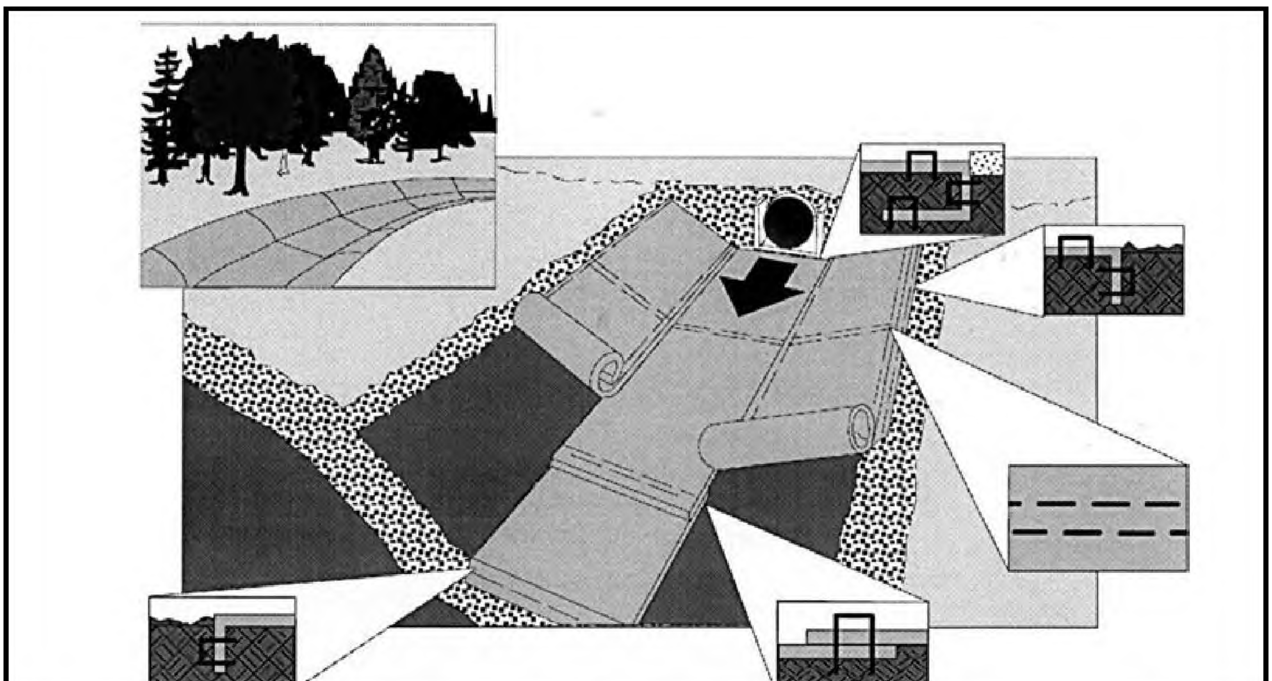


Figure 6.32 Typical installation of erosion control blankets in a channel - Consult manufacturer for recommendations on proper installation of staple patterns, overlap and keying edges.

Erosion Control Blankets

Blanket Installation

Install erosion control products in accordance with the manufacturer's recommendations and specifications, including check slots and stapling materials.

Anchor product so a continuous, firm contact (no tenting) with the soil surface/seed bed is maintained. Soil must be fine graded with no clods.

Note: Failure to do the above could result in soil erosion, which would require regrading and reseeding.

Construction Verification

Check finished grade, dimensions and staple spacing of erosion control blankets. Check materials for compliance with specifications.

- Movement of the blanket or erosion under the blanket is observed.
- Variations in topography on-site indicate erosion control mat will not function as intended; changes in the plan may be needed, or a blanket with a shorter or longer life may be needed.
- Design specifications for seed variety, seeding dates or erosion control materials cannot be met; substitution may be required. Unapproved substitutions could result in failure to establish vegetation.

Maintenance, Inspection and Removal

Inspect weekly and after storm events, until vegetation is established, for erosion or undermining beneath the blankets. If any area shows erosion, pull back that portion of the blanket, add tamped soil and reseed; then resecure the blankets.

If blankets become dislocated or damaged, repair or replace and resecure immediately.

Although some erosion control blankets are temporary, they are left in place to decompose and are not to be removed prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Common Problems and Solutions

Problem	Solution
Surface water flows under rather than over the blanket, causing erosion. This may be caused by poor contact between soil and the erosion control blanket.	Smooth grade or remove large clods and retrench or reanchor to direct water over blanket.
Tenting (air pockets under blanket), blanket movement or displacement is caused by blanket inadequately or improperly stapled.	Reinstall and ensure blanket is properly anchored.
Blanket or slope failure caused by unstable slope.	Determine cause of slope failure, stabilize slope and reinstall blanket.

Sediment Fence

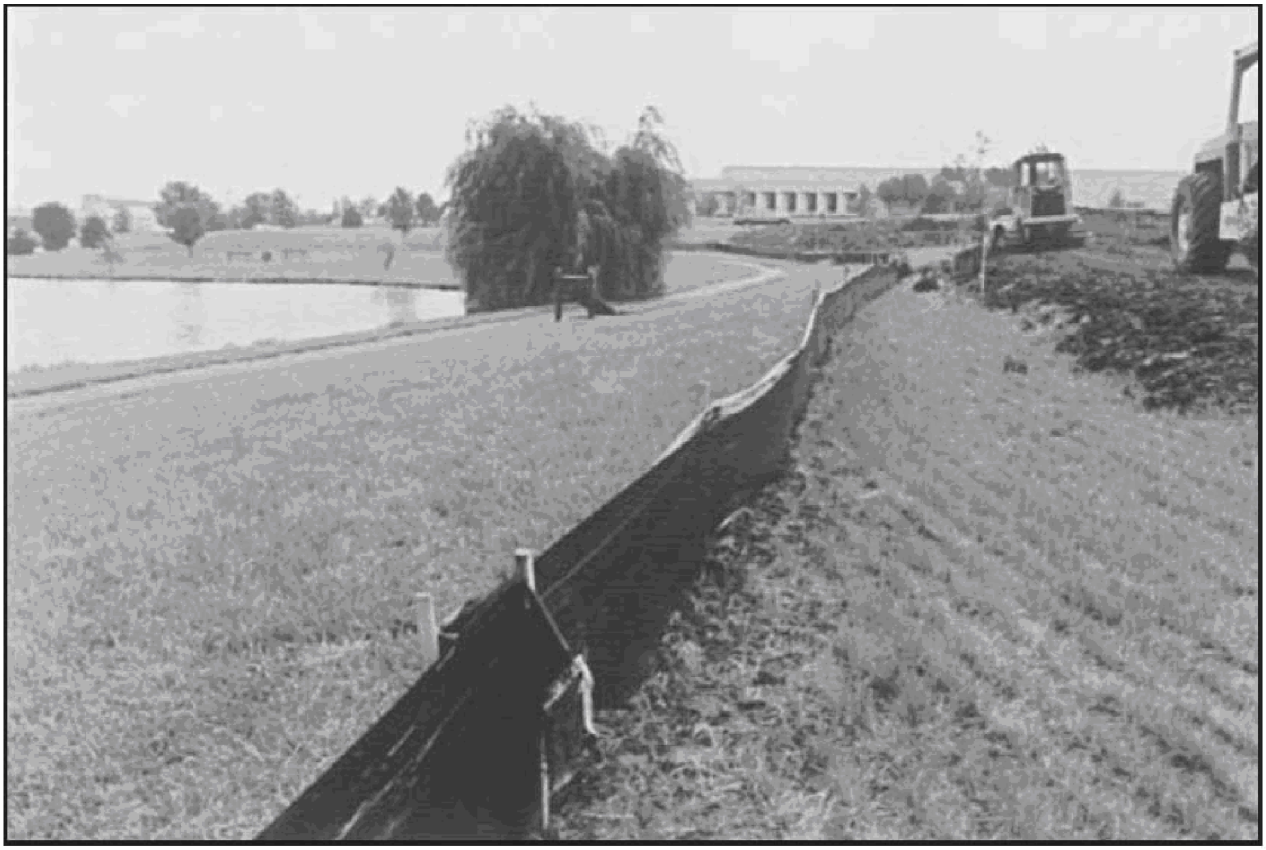


Figure 6.50 A properly installed sediment fence slows water flow long enough for the sediment to settle out. There should be no gaps under fence if heeled in properly. Source: C. Rahm, NRCS. Platte Co.

Practice Description

A sediment fence (often called a silt fence) is a temporary sediment barrier consisting of a geotextile fabric that is attached to supporting posts and trenched into the ground. Sediment-laden runoff ponds uphill from the sediment fence and runoff is temporarily stored to allow sediment to settle out of the water.

This practice applies where sheet erosion occurs on small disturbed areas. Sediment fences are intended to intercept and detain small amounts of sediment from disturbed areas in order to prevent sediment from leaving the site. Sediment fences can also prevent sheet erosion by decreasing the velocity of the runoff. Silt fence is not intended to be used in concentrated flow paths.

Recommended Minimum Requirements

Prior to start of construction, sediment fence placement and installment methods should be designed by a qualified professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process.

Drainage Area

Limit to 1/4 acre per 100 feet of fence. Further restrict the area by slope steepness as shown in Table 5.16.

Location

Fence should be built on a nearly level grade and at least 10 feet from the toe of the slope to provide a broad shallow sediment pool. Install on the contour, where fence can intercept runoff as a sheet flow; not located crossing channels, waterways or other concentrated flow paths; not attached to existing trees; and not located vertically up the slope (at a right angle to the slope.)

J-Hook

Silt fence should not be used around the entire perimeter of the site unless it is a small, flat site. It should only be located at areas where stormwater flow discharges with overland or sheet flow. You can use silt fence to create small catchments of stormwater flow by creating a small J-hook shape with the silt fence. The drainage area should be less than 1/4 acre with little or no slope (see Figure 3.83).

Length

Maximum of 600 feet; flare ends of fence uphill to temporarily impound water as shown in Figure 5.32.

Geotextile

Commercially available silt fence fabric is almost exclusively woven geotextile fabric. Non-woven material has better flow through but poorer strength. A higher porosity geotextile would be a mono-filament fabric with larger voids between the woven threads.

Table 6.14 Typical Land Slope and Distance for Sediment Fence

Land Slope (percent)	Maximum Slope Distance* above Fence (feet)
Less than 2	100
2 to 5	75
5 to 10 greater than 10	50*

*** Follow manufacturers' recommendations for proper spacing.**

Spacing of Support Posts

A good minimum stand is 6-feet maximum for geotextile fabric supported by wire and 5-feet maximum for geotextile fabric without supportive wire backing. Follow the local design standards in your area and the site SWPPP.

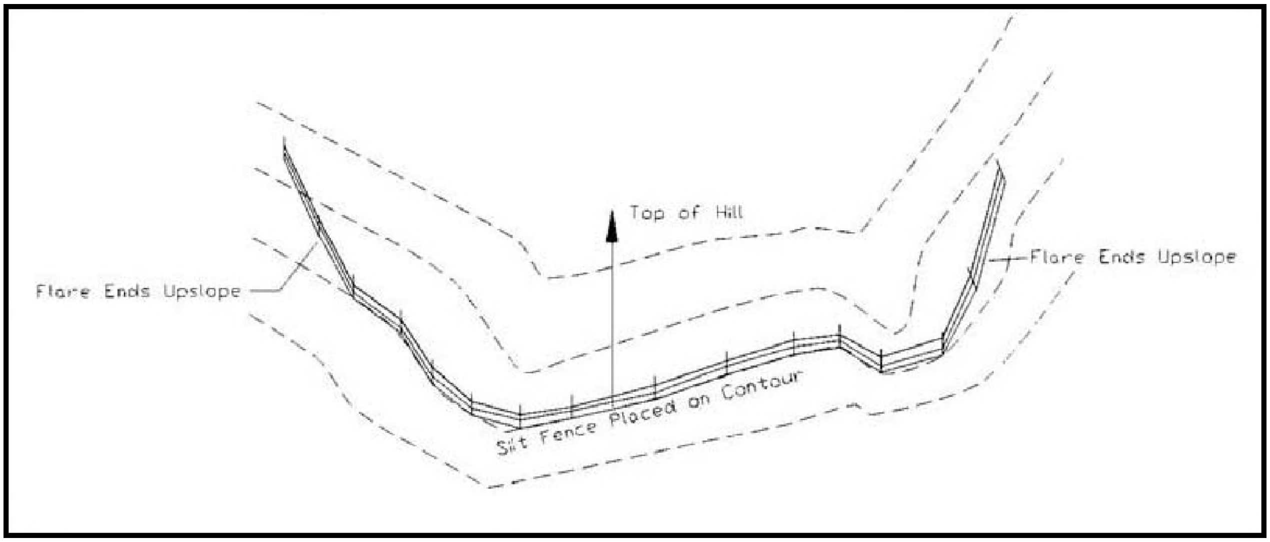


Figure 6.51 Placement of sediment fence

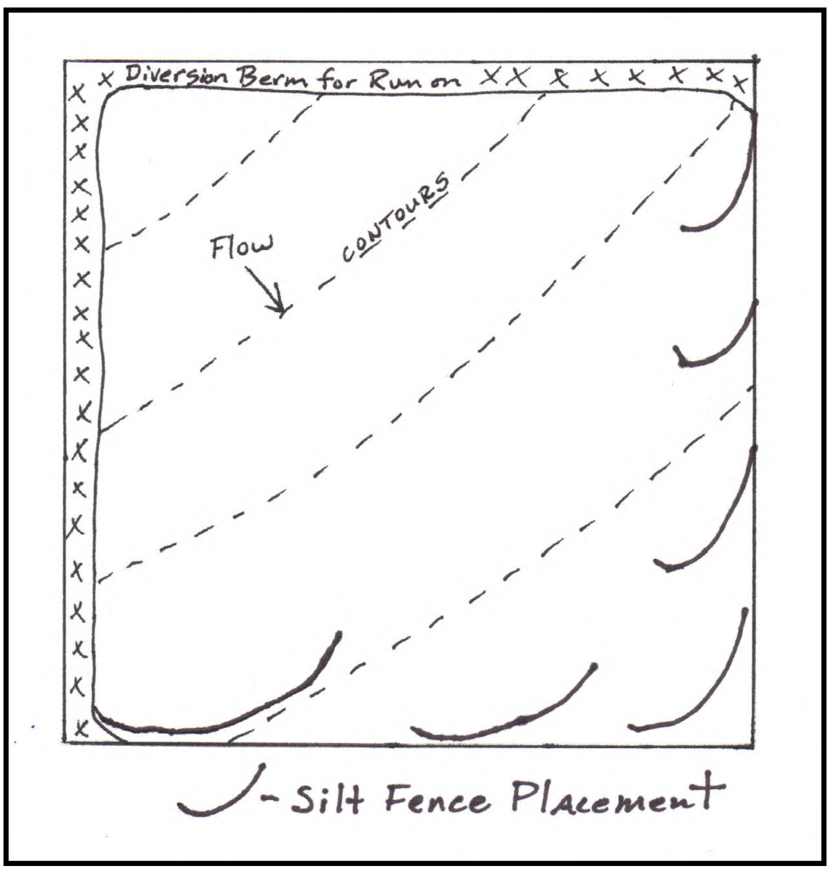


Figure 6.52 Placement of J-hook silt fence along the perimeter of a construction site to slow and pond small areas of stormwater runoff.

Proper Installation of Silt Fence

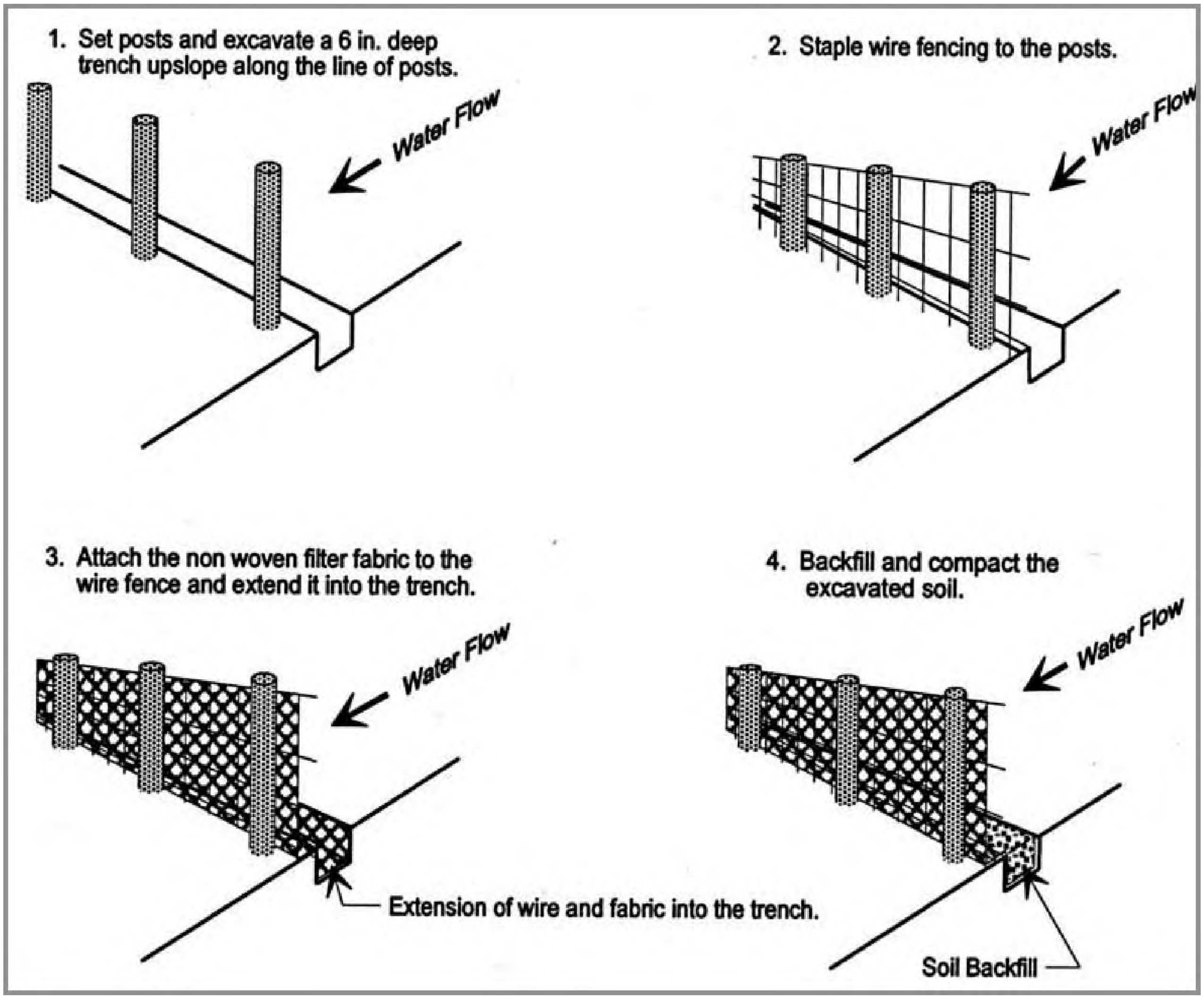


Figure 6.53 Proper Installation of silt fence

Construction

Site Preparation

- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Grade alignment of fence as needed to provide broad, nearly level area upstream of fence.

Fence Installation

- Dig a trench at least 6-inches deep along the fence alignment as shown in Figure 5.84.
- Drive hard wood or steel posts at least 24-nches into the ground on the downslope side of the trench. Space posts a maximum of 6-feet if fence is supported by wire, or 5-feet if no reinforcing wire fence is used.
- Fasten support wire fence to upslope side of posts, extending 6-inches into the trench as shown in Figure 5.84.
- Attach continuous length of fabric to upslope side of fence posts. Try to minimize the number of joints. Avoid joints at low points in the fence line. Where joints are necessary, fasten fabric securely to support posts and overlap to the next post.

- Place the bottom 1-foot of fabric in the 6-inch deep trench (minimum), lapping toward the upslope side. Backfill with compacted earth or gravel as shown in Figure 5.85.
- To reduce maintenance, excavate a shallow sediment storage area in the upslope side of the fence.
- Provide good access in areas of heavy sedimentation for clean out and maintenance.

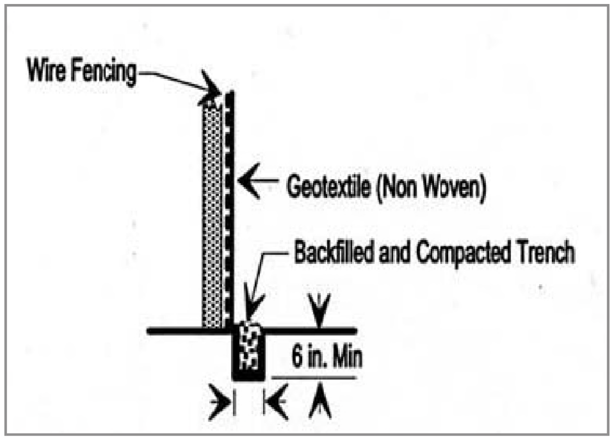


Figure 6.54 Detail of sediment fence installation

Reinforced Stabilized Outlet Installation

- Allow for safe bypass of storm flow to prevent overtopping failure of fence.
- Set outlet elevation so water depth cannot exceed 1.5 feet at the lowest point along the fence.
- Drive posts securely at least 24 inches into the ground, at a spacing of 5- to 6-feet depending on the use of wire fence reinforcement or not. Install a horizontal brace between the support posts to serve as an overflow weir and to support the top of the fabric.
- Immediately downslope of the fabric, excavate foundation for splashpad a minimum of 5-feet wide, 5-feet long and 1-foot deep. Place 1-foot of riprap in the excavated foundation. The surface of the riprap should be flush with the undisturbed ground (no outfall).

Erosion Control

Stabilize disturbed areas in accordance with landscape plan.

Construction Verification

Check finished grades and dimensions of the sediment fence. Check materials for compliance with specifications.

Maintenance, Inspection and Removal

Inspect sediment fences at least once a week and after each rainfall as dictated by your permit. Make any required repairs immediately.

- Immediately replace the fabric of the sediment fence should it collapse, tear, decompose or become ineffective.
- Remove sediment deposits as necessary to provide adequate storage volume for the next rain event and to reduce pressure on the fence. Take care to avoid damaging or undermining the fence during cleanout.
- Remove all fencing materials and unstable sediment deposits and bring the area to grade and stabilize it after the contributing drainage area has been properly stabilized.
- Remove the temporary sediment fence and stabilize the site prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Troubleshooting

Consult with registered design professional if any of the following occur:

- Variations in topography on-site indicate sediment fence will not function as intended; changes in the plan may be needed.
- Design specifications for geotextile fabric, support posts, support fence, gravel or riprap cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.
- Fence is not installed on the contour or is installed across channels or other concentrated flow areas.
- Installation of sediment fence as designed appears to create a potential flooding hazard or directs runoff overflows into sensitive ecological areas.

Common Problems and Solutions

Problem	Solution
Overtopping, sagging or collapse of fence occurs; caused by the drainage area too large or too much sediment accumulation allowed before cleanout.	Increase sediment storage capacity upslope of fence or remove accumulation more frequently, then repair fence.
Collapse of fence due to high velocity or undercutting of fence; caused by approach too steep.	Reduce slope of approach area, or consult with a registered design professional.
Sagging or collapse of fence; caused by fence not adequately supported.	Add additional supports.
Undercutting of fence; caused by the bottom of fence not buried properly.	Reinstall fence using proper method of trenching.
Sagging, collapse or undercutting of fence; fence installed across drainage way.	Relocate fence away from drainage way. Silt fence should only be used adjacent to drainageway; other devices should be used across or within drainageway (see Rock Check Dam or Ditch Check).
Water runs on both sides of fence; fence installed vertically or at right angle to contour.	Relocate fence along contours.

Fence should never be used as a check dam or in concentrated flow paths.

Temporary Diversions

Figure 6.55 An unfinished temporary diversion routes sediment-laden storm water to a sediment basin. Temporary diversions should be shaped and protected with a turf reinforcement mat or rock. Establish permanent vegetation if the diversion will be used for one year or more. Source: K. Grimes, Soil and Water Conservation District. St. Charles Co.

Practice Description

A temporary diversion is a temporary ridge or excavated channel or combination ridge and channel. It is designed to either prevent runoff from flowing across the active construction site work areas and discharge it through stable, protected outlets or to divert sediment laden water to sediment traps. Temporary diversions are usually constructed by excavating a channel and using the excavated material to construct a ridge on the down slope side of the channel.

This practice applies wherever storm water runoff must be temporarily diverted to protect disturbed areas and slopes or to retain sediment on-site during construction. When a diversion is needed to direct runoff from undisturbed areas above the construction site around a disturbed area, it must be routed to a stabilized outlet. The diversion must be fully stabilized and non-erodible prior to receivingstorm water flows. Check dams may be installed within the diversion to reduce velocities and control flows better. A diversion of cleanstorm water flow should never be allowed to flow over disturbed areas and create erosion or pick up sediment in the flow. If the untreated flow mixes with sediment ladenstorm water on the construction site, it must be treated through a control device before it discharges off-site.

Recommended Minimum Requirements

Prior to start of construction, temporary diversions should be designed by a registered design professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process. Temporary diversions should be constructed to minimize erosion at the design flow.

Drainage Area

Less than 5 acres.

Ridge Design

- Side Slope: 2:1 or flatter; 3:1 or flatter where vehicles must cross.
- Top Width: 2.0 ft.
- Freeboard: 0.3 ft.
- Settlement: 10 percent of fill height.

Channel Design

- Side Slope: 2:1 or flatter; 3:1 or flatter where vehicles must cross.
- Grade: Stable, positive grade towards outlet, but not exceeding 2 percent.

Construction

Site Preparation

- Locate and mark the alignment of the diversion as shown on the plans. The alignment should maintain a stable, positive grade toward the outlet. Minor adjustments to the grade and alignment may be required by site conditions. Realign or elevate the diversion as needed to avoid reverse grade.

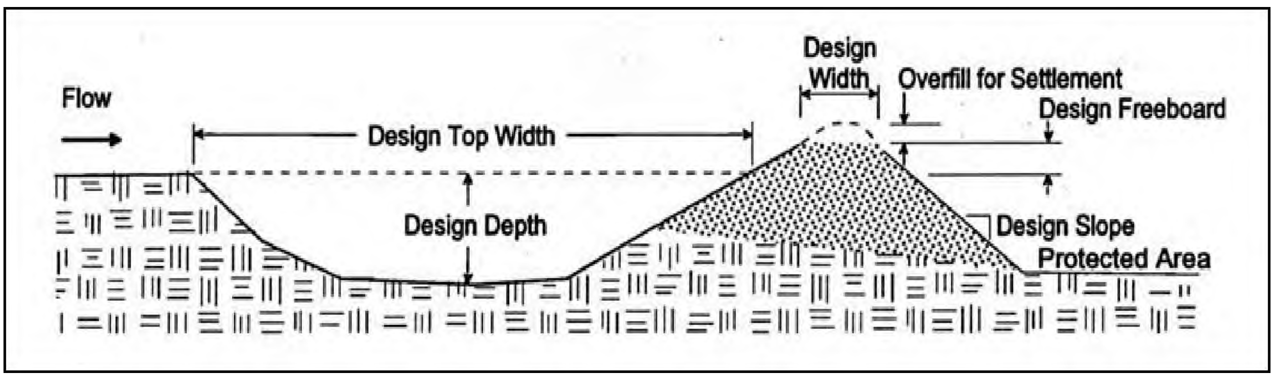


Figure 6.56 Typical temporary combination diversion.

- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Remove trees, brush, stumps and other unsuitable material from the site.
- Disk the base of the ridge before placing fill.

Grading

- Construct the diversion to the dimension and grades shown on the design.
- Build the ridge 10 percent higher than designed for settlement and compact with wheels of the construction equipment or sheep foot roller.
- Leave sufficient area along the diversion to permit clean out and regrading.

Erosion Control

- Stabilize the outlets in accordance with design plans during construction of the diversion.
- Vehicles should not be allowed to drive across through diversions.
- Stabilize ridges, side slopes and channels with vegetation or synthetic erosion control measures as specified in the design. Do not allow storm water flows to enter the channel until it is fully stabilized especially if it is being used to direct clean storm water around a disturbed area.
- Outlet should be nonerosive for design flow. Divert flow containing sediment to sediment trap or basin.
- Stabilize ridge with vegetation if in place more than 30 working days.
- Diversions should not be installed on slopes greater than 15 percent or where diversion flows are calculated to be greater than 3-feet per second over vegetation. If the diversion is constructed above a steep slope, install temporary slope drains or other stable outlet to control runoff and prevent erosion of the slope (see Temporary Slope Drains, Grass-lined Channel, Riprap-lined Channel or Turf Reinforcement Mats).

Construction Verification

- The field inspector should verify the dimensions shown on the plans for the following: depth, bottom width, top width, side slopes of channel and ridge, grade of channel bottom, ridge height and channel stabilization techniques.
- Check all of the finished grades and configuration of all channels to eliminate constrictions to flow and to ensure final discharge flows to sediment basins or stabilized outlets. Also check all ridges for low spots and stability.

Grading

- Construct the diversion to the dimension and grades shown on the design.
- Build the ridge 10 percent higher than designed for settlement and compact with wheels of the construction equipment or sheep foot roller.
- Leave sufficient area along the diversion to permit clean out and regrading.

Erosion Control

- Stabilize the outlets in accordance with design plans during construction of the diversion.
- Vehicles should not be allowed to drive across through diversions.
- Stabilize ridges, side slopes and channels with vegetation or synthetic erosion control measures as specified in the design. Do not allow storm water flows to enter the channel until it is fully stabilized especially if it is being used to direct clean storm water around a disturbed area.
- Outlet should be nonerosive for design flow. Divert flow containing sediment to sediment trap or basin.
- Stabilize ridge with vegetation if in place more than 30 working days.
- Diversions should not be installed on slopes greater than 15 percent or where diversion flows are calculated to be greater than 3-feet per second over vegetation. If the diversion is constructed above a steep slope, install temporary slope drains or other stable outlet to control runoff and prevent erosion of the slope (see Temporary Slope Drains, Grass-lined Channel, Riprap-lined Channel or Turf Reinforcement Mats).

Construction Verification

- The field inspector should verify the dimensions shown on the plans for the following: depth, bottom width, top width, side slopes of channel and ridge, grade of channel bottom, ridge height and channel stabilization techniques.
- Check all of the finished grades and configuration of all channels to eliminate constrictions to flow and to ensure final discharge flows to sediment basins or stabilized outlets. Also check all ridges for low spots and stability.

Maintenance, Inspections and Removal

- Inspect weekly and following each storm event.
- Remove debris and sediment from the channel and rebuild the ridge as needed.
- Check outlets and make necessary repairs immediately.
- Remove sediment from traps or check dams when they are 50 percent full.
- When the work area has been stabilized, remove the ridge and fill in the channel to blend with the natural ground. Remove temporary slope drains and stabilize all disturbed areas with permanent vegetation or other erosion control practices.
- Remove the temporary deversion and stabilize the site stabilized *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).
- Maintain vegetation in channel as shown in the design plan.

Common Problems and Solutions

Problem	**Solution**
Seepage is encountered during construction.	It may be necessary to install drains.
Variations in topography on-site indicate diversion will not function as intended.	Consult with a registered design professional.
Design specifications for seed variety, seeding dates or erosion control materials cannot be met.	Substitutions may be required. Unapproved substitutions could result in erosion and lead to diversion failure.
Final discharges from diversion channels cause ongoing erosion at the outlets.	Modifications to the diversion system need to be made or energy dissipation devices installed.
Overtopping of channel; caused by sedimentation in channel resulting in grade decreasing or reversing.	Realign or deepen the channel to maintain grade.
Overtopping of ridge due to low point in ridge where diversion crosses a natural depression.	Build up ridge.
Erosion and scour of the channel; caused by high velocity in channel.	Consult a design professional and install velocity dissipators such as check dams.

Breach of ridge caused by uneven channel grade and leading to erosion in channel before vegetation is established.	Repair channel and add more effective erosion control option-erosion control blanket, turf reinforcement mat, transition mat, etc.
Poor vegetation establishment caused by seepage or poor drainage in channel.	Install subsurface drains or stone channel bottom.
Erosion in channel caused by excessive grade in channel.	Consult design professional, repair channel, install an erosion resistant lining and velocity dissipators such as check dams or realign to reduce the grade.
Erosion; caused by excessive velocity at outlet.	Consult a design professional, install an outlet stabilization structure (see Rock Outlets or Energy Dissipators).
Runoff from a storm event causes blow out failure; caused by ridge not being compacted.	Repair and use construction equipment to compact.

Temporary Sediment Trap

Figure 6.73 Sediment traps are used to collect sediment laden runoff from disturbed areas on construction sites. Source: EPA

Recommended Minimum Requirements

Prior to start of construction, sediment traps should be designed by a registered design professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process. The sediment traps should be built according to planned grades and dimensions.

Location

- Where access can be maintained for sediment removal and proper disposal.
- Where runoff can be directed into basin at low velocity.

Drainage Area

- Below areas less than 5 acres in size. If the drainage area is larger, construct a sediment basin (see Sediment Basin).
- In the approach to a storm water inlet located below a disturbed area as part of an inlet protection system.
- Where failure of the structure will not result in loss of life, damage to homes, commercial or industrial buildings, main highways or railroads; or in the use or service of public utilities.

Structure Life

Limited to 18 months.

Sediment Storage
A minimum of 3,600 cubic square per acre of drainage area or sufficient to safely pass run-off greater than the two year frequency, 24-hour duration or design storm event.

Embankment
Dam Height
Less than five feet.

Top Width
At least five feet.

Fill Slopes
2.5:1 or flatter.

Settlement
10 percent or less.

Fill Material
Locally available soil; machine compacted in 8-inch lifts; moist when compacted; free of organic material, tree roots and waste material.

Spillway
A rock-lined open channel spillway should be constructed in the embankment to safely pass stormwater runoff. As an option, a perforated outlet riser can be used as the principal spillway.

Capacity
Sufficient to safely pass runoff from the two year frequency, 24-hour duration or design storm event.

Bottom Width
At least five feet.

Crest
A minimum of 18-inches lower than the top of the embankment.

Outlet
Include an apron at least five feet long to dissipate energy.

Filter
Geotextile should be placed between the embankment soil and the rock in the spillway section.

Construction
Site Preparation
- Locate the temporary sediment trap in an upland area as close to the sediment source as possible, considering soil type, pool area, dam length and spillway conditions.
- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Follow all federal, state and local requirements on impoundment sites.
- Clear, strip and grub the foundation of the dam to minimum depth of 4-inches, removing all woody vegetation, rocks and other objectionable material. Dispose of trees, limbs, logs and other debris in designated disposal areas.
- Divert off-site run-on from all undisturbed areas away from the sediment trap.
- Excavate the sediment trap (if necessary), stockpiling and stabilizing any surface soil having high amounts of organic matter for later use.

Embankment

- Scarify the base of the embankment before placing fill.
- Use fill from predetermined borrow areas. Fill should be clean, stable mineral soil free of organics, roots, woody vegetation, rocks and other debris, and must be wet enough to form a ball without crumbling, yet not so wet that water can be squeezed out.
- Compact the fill material in 8-inch continuous layers (maximum) over the length of the dam. (One way is by routing construction equipment over the dam so each layer is traversed by at least one wheel of the equipment.)

Open Channel Spillway

- Excavate a trapezoidal outlet section in the compacted embankment.
- Install geotextile fabric on the base of the channel, extending it up the sides to the top of the embankment.
- Place specified stone to the lines and grades, working smaller stones into voids to achieve a dense mass. The spillway crest should be level with a minimum width of five feet.
- Construct a stone outlet apron below the toe of the dam on level grade until a stable condition is reached (5-feet minimum).
- The base of the stone outlet should be at least two feet thick.
- Make the edges and end of the stone apron section flush with the surrounding ground.
- Cover the inside face of the stone outlet section with a 1-foot layer of well graded stone (2-inch minus).

Set a clean-out measurement stake in the basin at a height equal to one-half the distance from the bottom to the spillway crest.

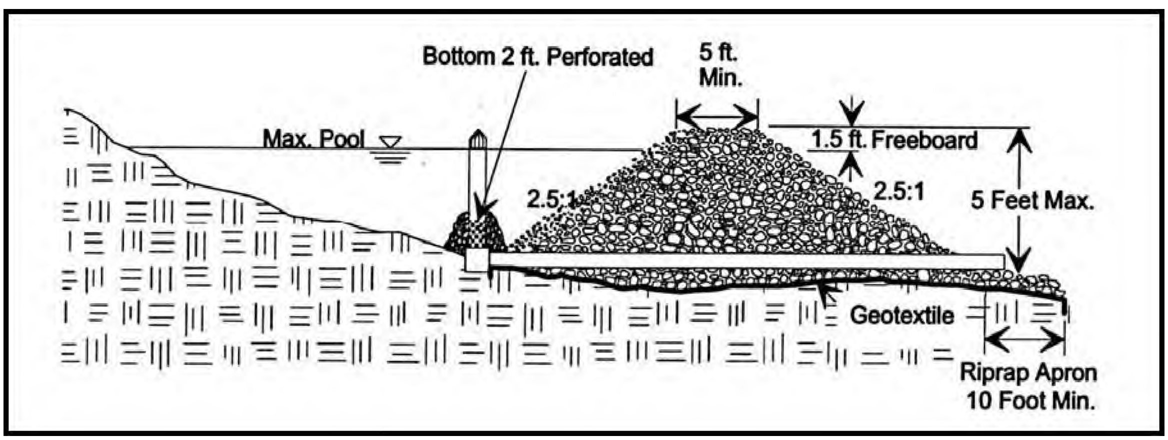


Figure 6.74 Temporary Sediment Trap with Spillway Riser

Optional Spillway Riser Construction

- Clear all vegetation and roots from the pipe foundation; prepare the bedding.
- Situate the spillway pipe and riser (minimum 18-inch diameter) on a firm, even foundation.
- Align the pipe and construct with the bell end of the pipe facing upstream. Around the barrel, place a 4-inch layer of moist, clayey, workable soil (not pervious material, such as sand, gravel, or silt), and compact with hand tampers to at least the density of the foundation soil. Don't raise the pipe from the foundation when compacting under the pipe haunches. Connect the pipe to the riser.

- Perforate the bottom 2 feet of spillway riser with 1/2 inch diameter holes spaced 3-inches apart (or use a manufactured perforated riser) for draining the sediment trap. Wrap the riser with geotextile fabric.
- Embed the riser at least 12-inches into concrete. The weight of the concrete should balance the buoyant force acting on the riser. Buoyant Force = Volume of Riser x 62.4 lbs./ft.^{3}
- Surround the entire riser with two feet of clean uniformly graded stone.
- At the pipe outlet, install a riprap apron at least five feet wide and 10 feet long. The riprap should be a minimum of 6-inches in diameter (see Rock Outlets).
- Dewatering can also be accomplished with a skimmer (see Skimmers).

Erosion Control

- The size of disturbed areas should be minimized. Stabilize all disturbed areas immediately after construction. Establish vegetation and erosion controls within 14 days after construction is complete.
- Divert sediment-laden water to the upper end of the temporary sediment trap to improve trap effectiveness.
- Direct all runoff into the basin at low velocity.

Safety

Because temporary sediment traps will likely impound water, the following precautions should be taken:

- Avoid steep slopes; the slopes around the temporary sediment trap should be 2.5:1 or flatter; 3:1 if maintained by tractors or other machinery.
- Fence area and post warning signs if trespassing is likely.

Construction Verification

- Check finished grades and dimensions of the temporary sediment trap.
- Check materials for compliance with specifications.

Maintenance, Inspection and Removal

- Inspect the temporary sediment trap weekly and after each storm event.
- Remove and properly dispose of sediment on an upland area to dry and be stabilized when it accumulates to one-half the design volume, as indicated by the clean-out stake.
- Periodically check the embankment, spillway and outlet apron for erosion damage, settling, seepage or slumping along the toe, and repair immediately.
- Replace the spillway gravel facing if it becomes clogged.
- Inspect vegetation and reseed if necessary.
- Replace any displaced riprap, being careful no replacement rock is above the design grade.
- Remove the temporary sediment trap after the drainage area has been permanently stabilized, inspected and approved. Do so by draining any water, removing the sediment to a designated disposal area, grading the site to blend with the surrounding area; then stabilize.
- Remove the temporary sediment trap and stabilize the site prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Troubleshooting

Consult with a registered design professional if any of the following occur:

- Variations in topography on-site indicate sediment trap will not function as intended.
- Design specifications for fill, pipe, seed variety or seeding dates cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Common Problems and Solutions

Problem	Solution
Embankment overtopping and possible failure of the structure; caused by inadequate spillway size.	Increase size of spillway.
Overtopping and possible failure; caused by extensive embankment settling.	Add additional fill to bring embankment back to design grade.
Erosion and displacement of rock; caused by rock outlet apron not extending to stable grade.	Extend apron.
Erosion of spillway or embankment slopes; caused by inadequate vegetation or rock size in spillway too small.	Improve vegetation, incorporate rolled erosion control product, or replace rock with larger size.
Settling of embankment; caused by inadequate compaction or use of unsuitable soil.	Add fill in settled areas to restore embankment to original grade.
Structural failure; caused by inadequate compaction due to construction with dry soil.	Replace failed material and compact to original grade.
Slumping failure; caused by overly steep slopes.	Repair damage and flatten slope without reducing the storage volume.
Piping failure; caused by too steep of a slope between stone spillway and earth embankment.	Flatten slope, then repair piping damage.
Inadequate storage capacity; caused by sediment not being properly removed.	Remove sediment on a regular schedule.
Inadequate storage capacity; caused by having a greater are a contributing sediment than originally designed.	Stabilize the disturbed area contributing to the trap or regrade the construction site and add additional traps to better distribute sediment laden storm water among the traps to handle the sediment discharging to the drainage area.
Safety or health hazard; caused by ponded water due to sediment clogging the gravel on the upstream slope of the riprap.	Remove sediment and install security fence if necessary.

Sediment Basin

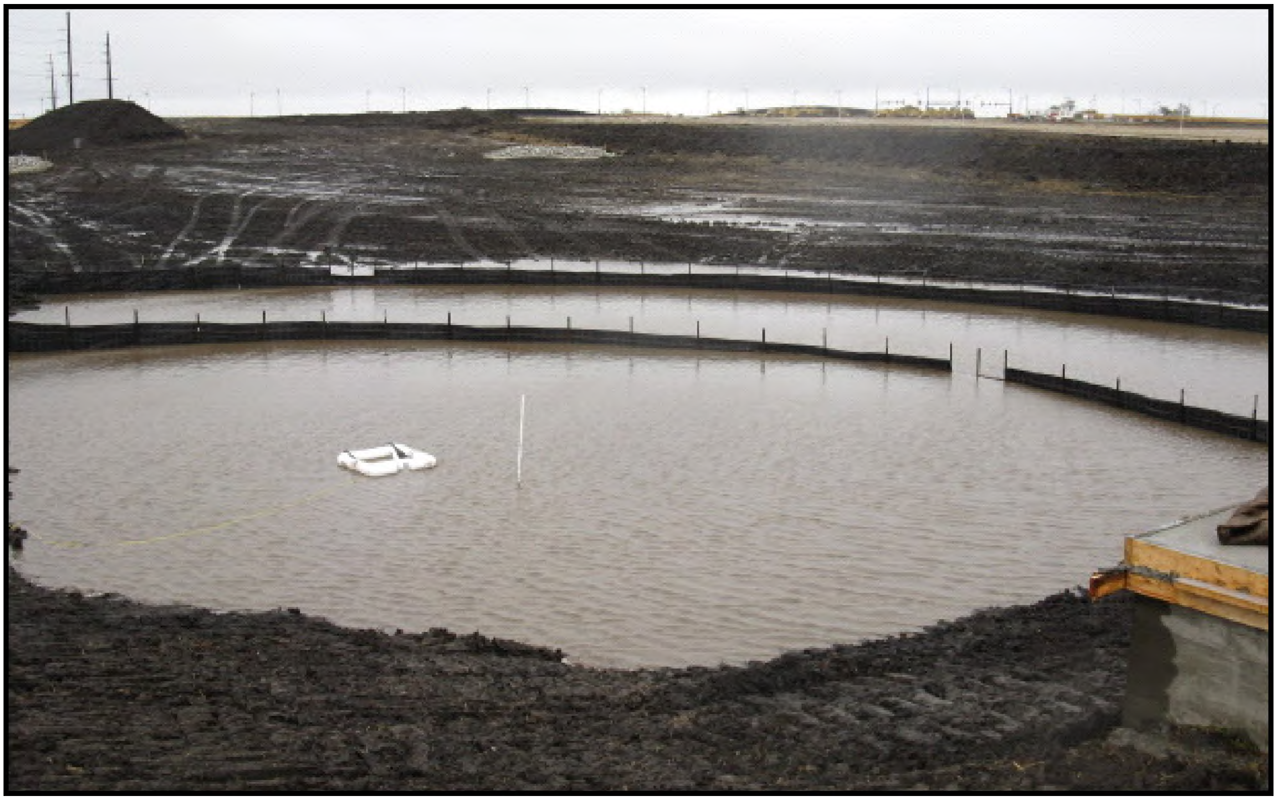


Figure 8.89 A sediment basin can be used to pretreat sediment-laden water before it discharges from the construction site. Source: BFA Inc.

Practice Description

A sediment basin is a temporary pond constructed to contain sediment-laden storm water for an extended period of time prior to the storm water discharging from the basin. A sediment basin is temporary and should be removed or retrofitted prior to any final construction activities that would make these features a permanent detention or retention pond, after the entire contributing drainage area is stabilized.

This practice applies where other erosion control measures are insufficient to prevent off-site sedimentation. The purpose of a sediment basin is to detain sediment-laden runoff from disturbed areas in wet storage long enough for most of the sediment to settle out.

Recommended Minimum Requirements

Prior to the start of construction, sediment basins should be designed by a registered design professional. Plans and specifications should be referred to by the site superintendent and field personnel throughout the construction process and anytime maintenance practices are required.

Build the sediment basin according to planned grades and dimensions.

Dam Height

10 feet or less.

Contributing Drainage Area

On project sites greater than 10 acres, contributing area is limited to 20 acres or less.

Structure Life

Limited to 10 years.

Detention

At least 24 hours or per local requirements.

Storage Volume

Minimum of 3,600 cubic feet per acre of contributing drainage area (pervious or impervious).

Trap Efficiency

The length to width ratio of the basin should be 2:1 or greater; 5:1 is optimal to capture fine sediments. Locate the inlet as far as possible upstream from the outlet.

Short Circuiting

Design the inflow to the pond as far away from the discharge point as possible. If not possible, design a baffle, weir or wall between the inflow and outflow to increase distance and travel time so there is maximum settling time prior to storm water discharge.

Embankment

- Top Width: At least 6 feet.
- Side Slopes: 2.5:1 or flatter; 3:1 where maintained by tractor or other equipment.
- Settlement: Allow for at least 10 percent.
- Fill material: Stable moist soil compacted in lifts less than 8 inches.

Anti-seep Devices

Either of the following is recommended:

- Use at least two watertight anti-seep collars around the outlet conduit; collars should project 1- to 3-feet from the pipe.
- A sand diaphragm (see Glossary).

Risers

- Hold risers in place with an anchor or large foundation to keep them from becoming buoyant.
- Install appropriate inlet protection on the riser.
- Pipe size for the primary conduit should restrict discharge into the natural drainage area at a rate and volume of storm water that meets the local regulatory requirements and the design plan.

Emergency Spillway

- Constructthe spillway in undisturbed soil in a location that will not erode the dam.
- Cross Section: Trapezoidal-shaped with side slopes of 3:1 or flatter
- Control Section: Level, straight and at least 20 feet long. The spillway should have a minimum width of 10 feet.
- Stabilization: Stabilize with vegetation, erosion control blankets or other erosion control stabilization practices. Install rip-rap, turf reinforcement mats, transition mat or other appropriate material to finished grade if the spillway is not to be vegetated.

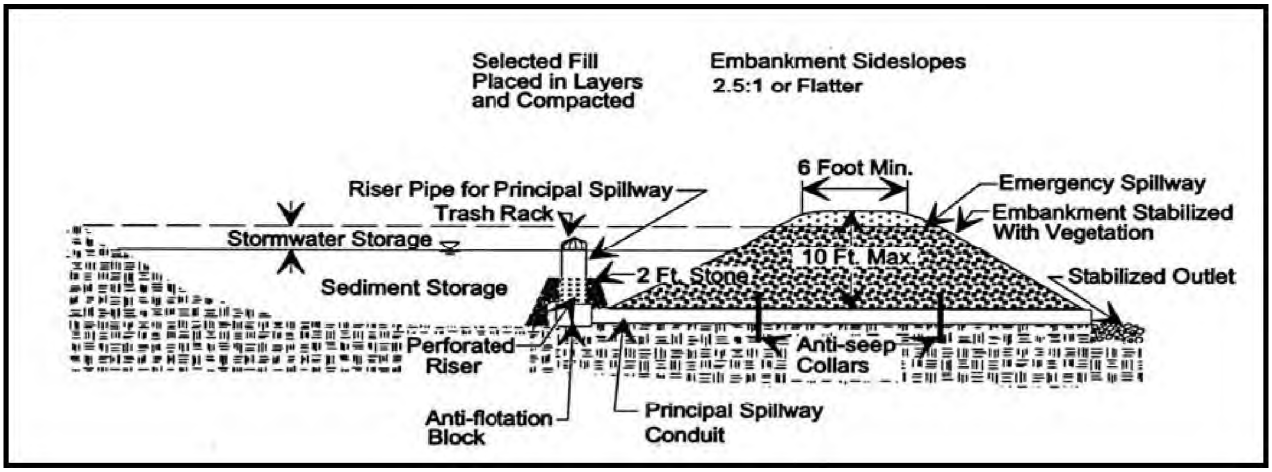


Figure 6.90 Typical Sediment Basin

Construction

Locate the sediment basin as close to the sediment source as possible, considering soil type, pool area, dam length, spillway conditions and proximity of sensitive habitats.

Site Preparation

- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Follow all federal, state and local requirements for impoundments. Clear, grub and strip the dam foundation, removing all woody vegetation, rocks and other objectionable material.
- Dispose of trees, limbs, logs and other debris in designated disposal areas.
- Excavate the foundation (outlet apron first), stockpiling any surface soil having high amounts of organic matter for later use.

Principal Spillway

- Construct a level sediment pool bottom to aid in sediment clean out. Situate the spillway barrel (pipe) and riser on a firm, even foundation. Prepare the pipe bedding.
- Place a 4-inch layer of moist, clayey, workable soil (not pervious material such as sand, gravel or silt) around the barrel, and compact with hand tampers to at least the density of the foundation soil. Don't raise the pipe from the foundation when compacting under the pipe haunches.

  Perforate the lower half of the riser with 1/2-inch diameter holes spaced 3 inches apart or use a manufactured perforated riser.
- Embed the riser at least 12 inches into concrete, which serves as an anti-flotation block. The weight of the concrete should balance the buoyant force acting on the riser.

$$\text{Buoyant Force} = \text{Volume of Riser} \times 62.4\ \text{lbs/ft}^3$$

- Surround the riser with 2- to 3-inch diameter clean stone to the height of the perforations on the riser. The stone footprint diameter should be 2 feet for every 1 foot of height.
- Place a domed inlet protector or steel trash rack around the riser inlet. The inlet protection should include overflow design. Trash rack openings should be no more than 4- to 6-inches square.
- At the pipe outlet, install a riprap apron at least 5 feet wide and 10 feet long to a stable grade.

Embankment

- Scarify the foundation of the dam before placing fill.
- Use fill from predetermined borrow areas. It should be clean, stable soil free of roots, woody vegetation, rocks and other debris; and must be wet enough to form a ball without crumbling, yet not so wet that water can be squeezed out.
- Place the most permeable soil in the downstream toe and the least permeable in the center portion of the dam.
- Compact the fill material in 6- to 8-inch continuous lifts over the length of the dam.
- Protect the spillway barrel with 2 feet of fill compacted with hand tampers before traversing over the pipe with equipment.

Emergency Spillway

- Construct and compact the dam to an elevation 10 percent above the design height to allow for settling.
- Place a reference stake indicating the sediment clean out elevation (50 percent of design elevation).
- Construct the spillway in undisturbed soil around one end of the embankment and locate it so that any flow will return to the receiving channel without damaging the embankment.

Stabilize the spillway as soon as grading is complete with vegetation, erosion control blankets or other erosion control stabilization practice; install riprap, TRM, transition mat or other appropriate material to finished grade if the spillway is not to be vegetated.

Erosion Control

- Minimize the size of all disturbed areas. Vegetate and stabilize all disturbed areas as soon as construction is complete.
- Divert runoff from undisturbed areas away from the basin.
- Use temporary diversions to prevent surface water from running onto disturbed areas.
- Divert sediment-laden storm water runoff to the upper end of the sediment basin (as far from the outlet or spillway as possible) to improve trap effectiveness. A forebay may also be incorporated at the basin inlet to dissipate energy.
- Direct all runoff into the basin at a low velocity (channel slope less than one percent).
- Vegetate and stabilize all disturbed areas immediately after construction.

Safety

Because sediment basins that impound water are hazardous:

- Avoid steep slopes; slopes around the sediment basin should be 2.5:1 or flatter; 3:1 where maintained by tractor or other equipment.
- Fence the area and post warning signs if trespassing is likely.
- Drain the basin between storm events.

Construction Verification

Check the finished grades and configuration for all earthwork. Check elevations and dimensions of all pipes and structures.

Maintenance, Inspection and Removal

- Inspect the sediment basin weekly and after each storm event.
- Remove and properly dispose of sediment when it accumulates to one-half the design volume. Proper disposal of sediment may entail placement at a stock pile or other area up gradient of the pond. Spread it out to allow drying and then stabilize it.
- Check the embankment, emergency spillway and outlet for erosion damage, piping, settling, seepage or slumping along the toe or around the barrel and repair immediately.
- Remove trash and other debris from the riser, emergency spillway and pool area.
- Clean or replace the gravel around the riser if the sediment pool does not drain properly.
- Remove the basin after the drainage area has been permanently stabilized, inspected and approved. Do so by draining any water (see Dewatering), removing the sediment to a designated disposal area, smoothing the material to blend with the surrounding area; and then stabilize. If this temporary sediment basin is to be converted to a permanent storm water control measure, or SCM, such as a detention, retention or infiltration basin, refer to your plans and specifications. Make sure the site is entirely stabilized before the permanent device becomes operational (no sediment-laden water should be entering the SCM.)
- Remove the temporary device and stabilize the site prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter 1 -Missouri Permit Requirements) for termination of permit coverage.

Common Problems and Solutions

Problem	Solution
Seepage is encountered during construction.	It may be necessary to install drains.
Variations in topography on-site indicate sediment basin will not function as intended.	Consult with registered design professional.
Design specifications for fill, pipe, seed variety or seeding dates cannot be met.	Substitutions may be required. Unapproved substitutions could lead to failure.
Piping failure along conduit caused by improper compaction, omission of anti-seep collar, leaking pipe joints or use of unsuitable soil.	Repair embankment using proper construction methods and materials.
Erosion of spillway or embankment slopes caused by inadequate vegetation or improper grading and sloping.	Repair using proper grades and slopes. Stabilize with vegetation, erosion control blankets or other erosion control stabilization practices. install rip-rap, turf reinforcement mats, transition mat or other appropriate material to finished grade if the spillway is not to be vegetated.
Riser and barrel blocked with debris	Remove debris and install trash guard.

Problem	Solution
Overtopping of the principal and emergency spillway caused by undersized principal or spillway design.	Repair erosion damage and reevaluate spillway design.
Frequent operation of emergency spillway and increased erosion potential caused by lack of maintenance..	Clean the sediment out of the basin on a regular basis..
Frequent operation of emergency spillway and increased erosion potential caused by undersized principal spillway..	The sediment basin was designed with insufficient volume. Enlarge the basin or install additional sediment traps upstream in thee watershed.
Slumping or settling of embankment caused by inadequate compaction or use of unsuitable soil..	Repair damage with suitable, well compacted material..
Slumping failure caused by steep slopes.	Flatten slopes.
Severe erosion below principal spillway caused by inadequate outlet protection.	Install adequate outlet protection.
Turbid water coming out of outfall pipe; small clay particles do not have sufficient time to settle out. The primary problem is that too much sediment is coming from above. Take needed steps to reduce thee overloading of sediment to the basin.	Consult with the registered design professional to pursue additional features such as installation of a pre-sediment basin, addition of bafflesor addition of particle curtains..

Do not apply water clarifying chemicals such as polymers to the final sediment basin. If the choice is made to use water clarifying chemicals earlier in the treatment process, see Chemical Application for Turbidity Reduction. Note any restrictions or controls required in federal, stateor local regulations.

Dry Pond (Detention)

Figure 6.118 Dry Pond. Source: ABC's of BMP's, LLC

Practice Description

A dry pond is a surface storage basin or facility designed to provide water quantity control and limited water quality benefits through stormwater detention or extended detention. Dry ponds, also known as dry detention basins or dry detention ponds, are ponds designed to store and then release stormwater runoff from a specified design rainfall event. Unlike wet ponds, dry ponds do not have a permanent pool.

The historical purpose of a dry pond is to reduce the peak flow rate of stormwater runoff– essentially providing flood control. These types of dry ponds seldom meet the overall quantity and quality objectives as a stand alone practice. Flood detention ponds were not designed to detain stormwater from small flow events.

Variations of dry ponds include:

- Dry pond for peak flow rate (flood) control only (Figure 6:118).
- Extended detention dry pond for limited water quality control and for channel protection .
- Combination dry pond – combining flood control with extended detention.

Sometimes a dry pond is an acceptable option for achieving flood detention. However, volume reducing (i.e., retention) practices are preferred over flood detention practices as a method of flood control in the lower portion of a major watershed or drainage basin. A dry pond should also be a last resort option in the upper portion of the watershed, because many alternative practices are available to simultaneously reduce volume, protect against flooding and achieve water quality. As an example, Figure 6:119 illustrates a similar 100-year flood detention benefit is achieved by retaining 1.1-inches of rainfall retention in multiple mircoscale practices across a residential development.

Given adequate space in the urban environment, dry ponds can be used to retrofit a drainage area to provide flood control, channel protection and in some cases temperature control. As noted above, it is also important to note where in the major watershed the detention basin is located. As a rule of thumb, detention basins are most effective when placed in the upper 1/3 of a major watershed. Otherwise, detention basins provided in the lower portion of the watershed will likely release water at the same time flow from the upper portion of the watershed reaches the same point. This can make downstream flooding and erosion problems worse by forcing even larger volumes of water into the downstream channel.

Dry ponds are sometimes converted from construction site sediment basins through the removal of sediment, addition of vegetation and modification of the basin outlet structure. Dry ponds are permanent “post construction” ponds as opposed to a sediment basin, and therefore should not be designed or used to store construction site sediment.

Dry ponds should not be put into use until after all construction is complete and the site is completely stabilized. These ponds detain the stormwater flow from rain events but do not hold it for long periods of time. These are designed to be fully vegetated on bottom and side slopes. The outlet structure is designed and built at the lowest point in the basin, allowing the basin to fully drain. Dry ponds should be constructed so all stormwater is detained, not retained as in a retention or “wet” pond.

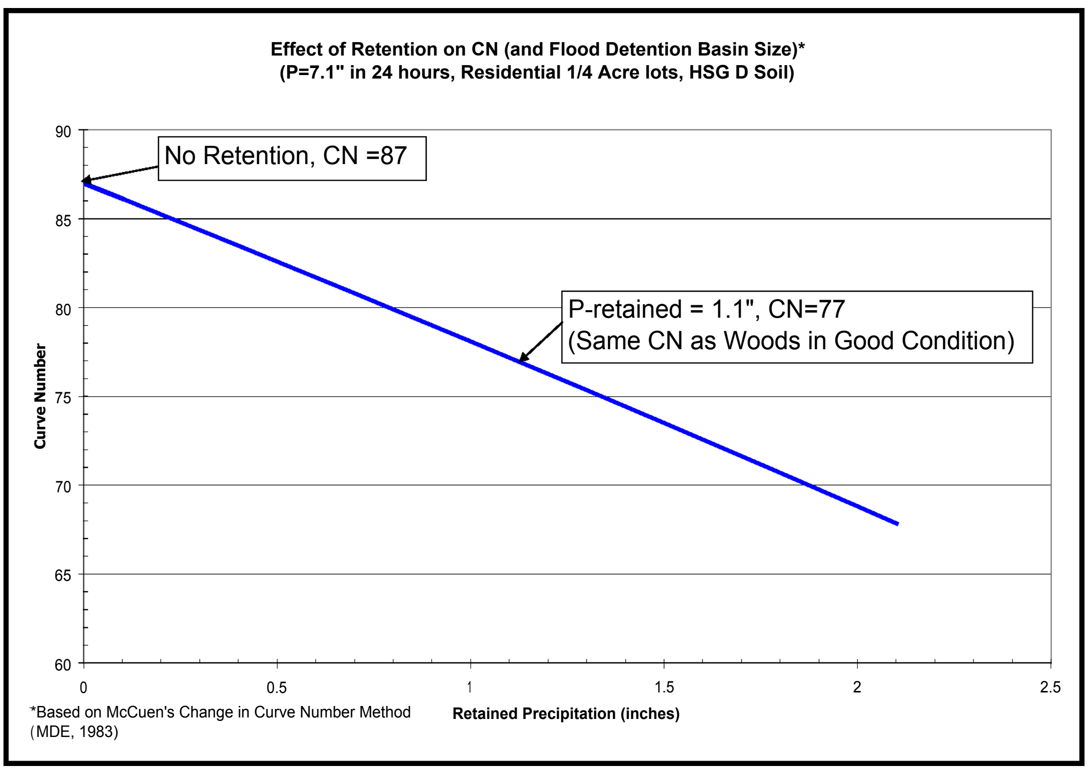


Figure 6.119 Effect of retention on curve number (and flood detention basin size). Source: Metropolitan St. Louis Sewer District

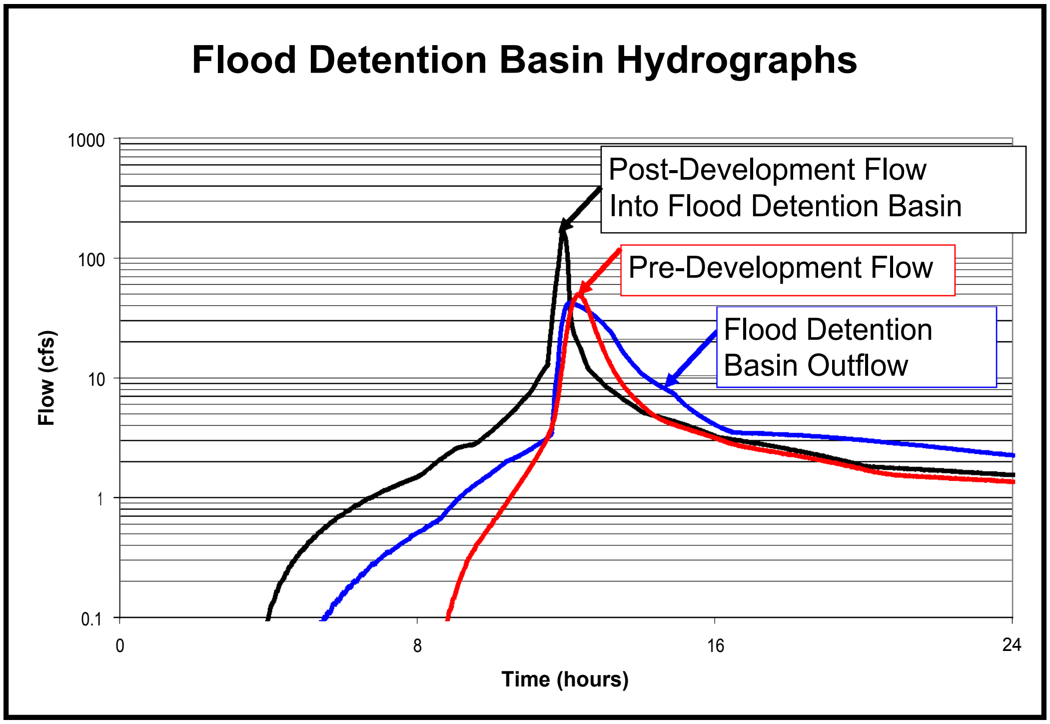


Figure 6:120 Dry pond for peak flow rate control only. Source: Metropolitan St. Louis Sewer District

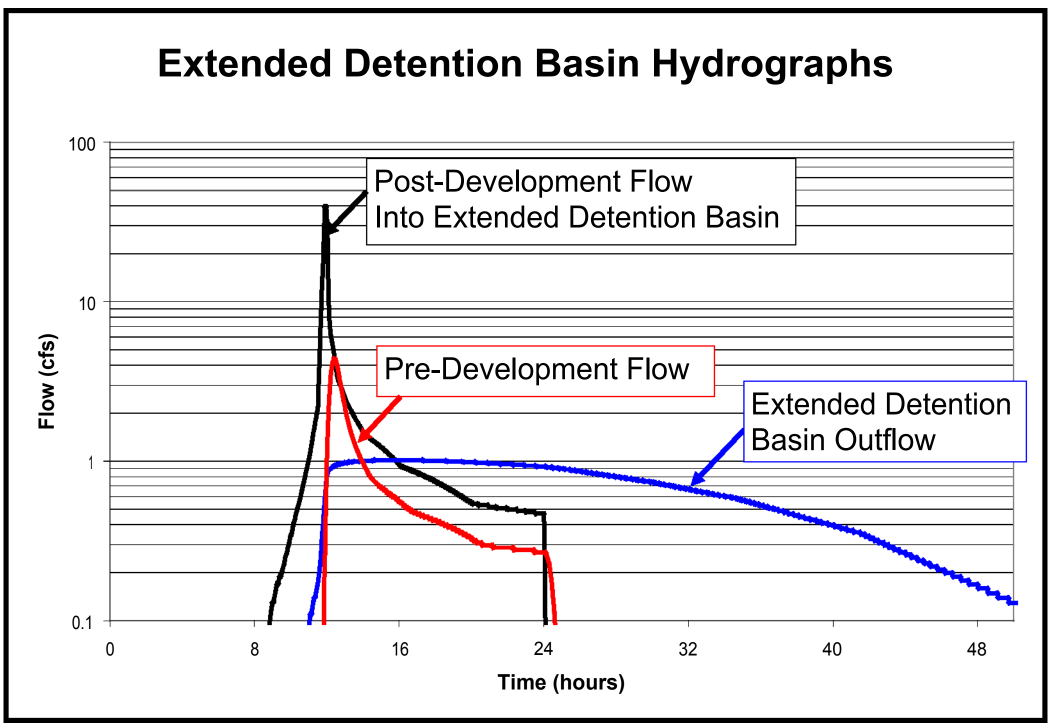


Figure 6.121 Extended detention dry pond for limited water quality control and for channel protection.
Source: Metropolitan St. Louis Sewer District

Pollutant Removal

As noted previously, the historical purpose of a dry pond is to reduce the peak flow rate of stormwater runoff – essentially providing flood control. The dry pond is often used to reduce the peak flow rate from stormwater events and may temporarily minimize flooding downstream. Dry ponds designed to provide extended detention can benefit downstream water quality by protecting downstream channels from the frequent storm events that cause streambank erosion. However, when used to remove settleable pollutants, studies show some of the sediment and other pollutants are re-suspended and then discharged in recurring storm events

See Appendix C for the reference publication *Stormwater BMPs: Selection, Maintenance and Monitoring.* Additionally, dry ponds are not effective removers of soluble pollutants. As such, this practice seldom meets the overall quantity and quality objectives as a standalone practice.

If water quality treatment is a goal of dry detention basin design and construction, a wet or extended stormwater pond design should be incorporated. Dry ponds should be used in conjunction with other practices, as part of an overall treatment series; they should include enhancements such as a sediment forebay, extended storage, a micropool at the outlet, a long shape to minimize short-circuiting or a combination of these features. Effectiveness of dry ponds varies significantly depending on design, incorporation of companion water quality practices and maintenance.

Dry ponds with concrete conveyance channels or pilot swales should not be used, because they convey polluted stormwater directly to stream resources. See Figure 6:122.

Sediment clean-out should be tested for toxicants in compliance with current disposal requirements if commercial or industrial land uses contribute to the catchment, or if visual or olfactory indications of pollution are noticed

Figure 6.122 Detention basin with concrete conveyance channel. Source: Metropolitan St. Louis Sewer District

Costs Considerations

According to the Stormwater Manager's Resource Center, construction costs vary considerably, but the estimated costs of a typical extended dry detention basin may range from $41,600 per one acre-foot pond to $1,380,000 for a 100 acre-foot pond.

Costs associated with required space should be considered, especially when other practices such as bioswales and rain gardens can be worked into the natural landscape and meet water quality requirements.

Consideration should be given also to the economic impacts to neighboring properties. According to Emmerling-Dinovo, a 1995 study found that dry ponds can actually detract from the perceived value of homes adjacent to a dry pond by between three and 10 percent. See the **Appendix C** reference for *Stormwater Detention Basins and Residential Locational Decisions* (1995.)

The estimated cost of maintenance is typically estimated at about three to five percent of the construction cost.

Recommended Minimum Requirements

Key considerations for constructing a dry pond is how big the pond should be, how the land should be graded, the location and size of the outlet structure and the elevation of drainage outlets. Typically, detention basins are designed through modeling to demonstrate specific design storm requirements that will be met. Deviation from the design can result in basin inefficiency at best, and intesifying of downstream flooding and erosion problems at worst.

Design should be in accordance with state-of-the-practice specifications aimed at achieving water quality criteria. When designed in conjunction with other appropriate runoff volume-reducing SCMs, detention basins may be reduced in size. Forebays may be provided at all major inflow points to capture coarse sediment, prevent excessive sediment accumulation in the main basin and minimize erosion by inflow. The basin may also be planted with dense, low-growing native or adaptive vegetation that can withstand periods of inundation and drought, require no mowing and provide aesthetic and wildlife benefits.

For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design* , St. Louis, Missouri. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region. See additional plant information resources in Appendix C.

Construction

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Follow all federal, state and local requirements for impoundment sites. See Chapter 1 for information about regulations and permit requirements.

Prior to start of construction, detention basins should be designed by a registered design engineer. Plans and specifications should be reviewed by the site superintendent and field personnel throughout the construction process. The detention basin should be built according to the planned grades and dimensions.

An example construction sequence follows:

- Construction should begin only when the erosion and sediment control measures are in place.
- The site should be prepared for excavation or construction of the embankment. Site preparation includes the removal of existing vegetation within the construction limits, as necessary for construction. Tree roots, rocks or boulders should be removed from the excavated area and disposed of in designated disposal areas.
- Embankments should be constructed. Inlet and outlet structures should be installed, per the construction plans.
- The final grading should include placement of planting soil.
- Seeding, planting and mulching should be completed as specified in the plans. The contractor should install geo-textiles and erosion control measures specified in the plans.
- After all tributary areas are sufficiently stabilized, remove temporary erosion and sediment controls. It is important for the swale to be stabilized before receiving upland flow.

Consult with the registered design engineer if any of the following occur:

- Seepage is encountered during construction.
- Variations in topography on-site indicate detention pond will not capture the drainage area intended.
- Design specifications for fill, pipe, seed/plant variety or seeding/planting dates cannot be met.
- Depression holds water long after the rain event, which does not allow vegetation to survive.
- Substitutions are required. Unapproved substitutions could lead to failure.

construction Verification

Check the finished grades and configuration for all elements. Check elevations and dimensions of all pipes and structures. If at final grade the basin storage volume is less than indicated on the plan (e.g., 10 percent less), orifice invert elevations vary more than 0.1' from plan, or if orifice size if different from plan, then the engineer should be consulted to determine if basin performance has been negatively impacted and if adjustments are needed.

Maintenance and Inspection

A specific operations and maintenance plan should be provided by the design engineer and transferred to the person responsible for long-term operations and maintenance. Adequate training should be provided as well. Typical maintenance requirements include the following:

- Inspect the detention basin after each storm event greater than 1-inch in 24 hours. Remove trash and other debris from the basin. Collected sediment should be removed when 10 percent of the basin design volume has been filled, or 50 percent of the sediment forebay is filled.
- Periodically (e.g., annually) check the embankment, emergency spillway and outlet for erosion damage, piping, settling, seepage or slumping along the toe or around the barrel and repair upon discovery.
- Remove nuisance vegetation on the embankment as needed during the growing season (e.g., April to October).
- Remove rodents that burrow into the dam.

Common Problems and Solutions

Problem	Solution
Piping failure along conduit; caused by improper compaction, omission of anti-seep collar, leaking pipe joints or use of unsuitable soil.	Repair damage, check pipe joints and seal leak if necessary. Use suitable soil for backfill. Consider installing anti-seep collar or pressure-injecting grout around the pipe.
Erosion of spillway or embankment slopes; caused by inadequate vegetation or improper grading and sloping.	Repair damage and establish suitable grade or vegetation. Perform a soil test and amend the embankment as needed to establish vegetation.
Slumping or settling of embankment; caused by inadequate compaction or use of unsuitable soil.	Excavate failed material and replace with properly compacted suitable soil.
Slumping; caused by steep slopes.	Excavate dislocated material and replace with properly compacted suitable soil. Consider flattening slope.
Erosion and caving below principal spillway; caused by inadequate outlet protection.	Repair damaged area and install properoutlet protection.
Basin not located properly for access; results in difficult and costly maintenance.	Improve access to site.
Ponding stormwater for long periods of time and dead vegetation caused by principal discharge area not at lowest elevation.	Check with the engineer to determine if the discharge can be lowered or if the basin can be filled. Re-vegetate damaged areas.
Frequent operation of emergency spillway, long-term ponding and increased erosion potential caused by principal discharge point too small.	Consider increasing capacity of principal discharge, install supplemental discharge or install suitable erosion protection in emergency spillway.
Stormwater released from pond or basin too rapidly; caused by discharge.	Consider resizing discharge and add additional energy dissipation at discharge location.
Unsuccessful vegetation establishment.	Consider selecting plants that are native species tolerant of both wet and dry cycles and appropriate for the plant zone. Deep rooted perennials are encouraged to increase the rate of infiltration. Inspect plans to ensure they are properly planted and have correct soil conditions. Properlywater them through establishment. Maintain plantings to make sure they are not taken over by noxious plants or weeds.

Wet Pond ("Retention")

Figure 6.123: Extended Wet Detention, Express Scripts Campus, Berkeley, MO.
Source: Metropolitan St. Louis Sewer District

Practice Description

Wet ponds are often referred to as stormwater ponds, retention ponds or wet detention ponds. A wet pond is designed to collect stormwater runoff in a permanent pool during storm events. The water stored in the pond is later displaced by new runoff. A wet pond can provide pollutant removal primarily through settling and microbial, plant and algal biological uptake. While wet ponds can provide water quality improvement, their role in runoff volume reduction is limited. Wet ponds are best used in combination with other stormwater control measures in an overall stormwater treatment train to achieve the desired affects of pollution control, storage and flow rate reduction. Many of the hydrograph principles that apply to dry ponds also apply to wet ponds. (See Dry Ponds.)

Variations of wet ponds include:

- Flow-Through (Wet) Pond (no extended detention, this pond has an essentially unrestricted spillway as its primary outlet, with its crest at the elevation of the permanent pool).
- Extended wet detention (extended detention storage is provided above the permanent pool).
- Water reuse pond (used primarily for irrigation.)

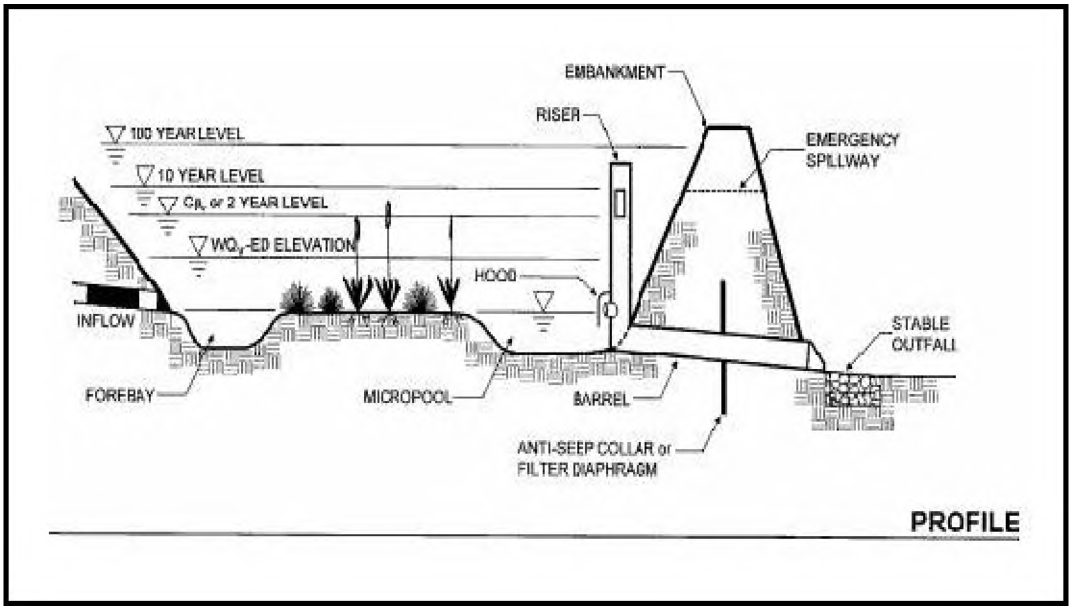


Figure 6:124 Wet Pond Cross Section Source: U.S. Environmental Protection Agency

The extended wet detention pond is a wet pond that works in tandem with a dry detention pond located above the permanent pool. During storm events, water is collected in the detention storage pond above and released over a period of 12 to 48 hours into the wet pond below.

Wet ponds can be used as a retrofit option in existing communities as modifications to existing detention facilities to enhance water quality treatment and downstream channel protection. If water quality, storage and reduced flow rate are the goals, wet ponds should be used in conjunction with other SCMs in an overall stormwater treatment train to achieve the best results. See Figure 6:102. At the very least, sediment and pollutant removal, as well as maintenance needs, can be enhanced through the use of multiple cells in succession.

Geese can often be attracted to wet ponds if the edges are mowed. However, unmowed native or adaptive vegetation around the edges will discourage geese and help to filter pollutants from stormwater runoff.

Additional Considerations

- Fluctuating water elevations make it difficult to establish plants.
- Use wet detention basins to treat runoff from stormwater hot spots, only if significantly separated from the groundwater table.
- Use of wet ponds is limited in dense urban areas due to the amount of space and drainage area required.
- Not appropriate for discharge to cold water resources, due to the potential for thermal pollution.
- Not appropriate for karst areas without significant consideration to leakage or sinkhole prevention.
- Safety is always a concern where permanent pools of water exist.

Cost Considerations

According to the Center for Watershed Protection, typical costs for wet detention ponds range from $17.50 to $35 per cubic meter ($0.50 to $1 per cubic foot) of storage area (CWP, 1998). The total cost for a pond includes permitting, design and construction and maintenance costs. Permitting costs may vary depending on state and local regulations. Typically, wet detention ponds are less costly to construct in undeveloped areas than to retrofit into developed areas. This is due to the cost of land and the difficulty in finding suitable sites in developed areas. The cost of relocating pre-existing utilities or structures is also a major concern in developed areas. Several studies have shown the construction cost of retrofitting a wet detention pond into a developed area may be 5 to 10 times the cost of constructing the same size pond in an undeveloped area. Annual inspection and maintenance costs can generally be estimated at three to five percent of the construction costs.

Recommended Minimum Requirements

The design should reflect the design criteria that could include the following key elements:

- An adequate contributing drainage area, typically more than 10 acres. A water balance assessment should be provided for smaller drainage areas.
- Natural high groundwater table.
- Maintenance of a permanent water surface.
- A length to width ratio of 2:1, or irregular shapes that maximize flow path between inlet and outlet points.
- An aquatic bench with diverse vegetation around the perimeter.
- Relatively impermeable soils, or lining of the pond bottom.
- A forebay for coarse sediment and trash collection.
- Outfall protection to prevent erosion.
- Access for maintenance.

The designer should review local requirements for site grading, drainage structures, erosion and sediment control, and potential invasive vegetation. In Missouri, dams with a height of 35 feet or greater require approval from the Missouri Department of Natural Resources' Dam Safety Program. (See Chapter 1 for information about permits and regulations.)

For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design* , St. Louis, Missouri. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region. See additional plant information resources in Appendix C.

Construction

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Follow all federal, state and local requirements for impoundment sites. See Chapter 1 for information about regulations and permit requirements.

Prior to start of construction, the wet pond should be designed by a registered design engineer. Typically, this SCM is comprised of a forebay, an embankment to create the basin(s), an outlet structure, a spillway for overflows and safe access.

Plans and specifications should be reviewed by the site superintendent and field personnel and followed closely throughout the construction process. The basin should be built according to the planned grades and dimensions. An example construction sequence follows:

- Construction should begin only when the erosion and sediment control measures are in place.
- The site should be prepared for excavation or construction of the embankment. Site preparation includes the removal of existing vegetation within the construction limits, as necessary for construction. All tree roots, rocks, or boulders should be removed from the excavated area.
- Rough grading of the basin should be completed carefully to ensure compaction of the bottom of the basin.
- Embankments should be constructed. Inlet and outlet structures should be installed, per the construction plans.
- The final grading should include placement of planting soil.
- Seeding, planting and mulching should be completed as specified in the plans. The contractor should install geo-textiles and erosion control measures specified in the plans.
- After all tributary areas are sufficiently stabilized, remove temporary erosion and sediment controls.

construction Verification

Construction verification needs for dry and wet ponds are similar. Check the finished grades and configuration for all elements. Check elevations and dimensions of all pipes and structures.

Maintenance and Inspection

A specific operations and maintenance plan should be provided by the design professional. After construction is complete and the detention basin is operational, operations and maintenance of each device is performed by the personnel identified in the operations and maintenance manual. Typical maintenance requirements include the following:

- Periodically check the embankment, emergency spillway and outlet for erosion damage, piping, settling, seepage or slumping along the toe or around the barrel and repair immediately.
- Clean and remove trash and vegetative debris from inlet and outlet structures, mow side slopes as needed.
- Semi-annual inspection for invasive vegetation.
- Annual inspection to monitor damage, hydrocarbon build-up, sediment accumulation and debris in inlet and outlet devices.
- Repair erosion and remove excess sediment from forebay as needed.
- Manage and harvest wetland plants annually.
- Renovate the facility when pool volume has been reduced significantly or when the pond becomes eutrophic (excessive in nutrients, resulting in algal blooms and poor water quality.)

Common Problems and Solutions

Problem	Solution
Piping failure along conduit; caused by improper compaction, omission of anti-seep collar, leaking pipe joints or use of unsuitable soil.	Repair damage, check pipe joints and seal leak if necessary. Use suitable soil for backfill. Consider installing anti-seep collar.
Erosion of spillway or embankment slopes; caused by inadequate vegetation or improper grading and sloping.	Repair damage and establish suitable grade or vegetation.
Slumping or settling of embankment; caused by inadequate compaction or use of unsuitable soil.	Excavate dislocated material and replace with properly compacted suitable soil.
Slumping; caused by steep slopes.	Excavate dislocated material and replace with properly compacted suitable soil. Consider flattening slope.
Erosion and caving below principal spillway; caused by inadequate outlet protection.	Repair damaged area and install proper outlet protection.
Basin not located properly for access; results in difficult and costly maintenance.	Relocate basin to more accessible area or improve access to site.
Ponding stormwater for long periods of time and dead vegetation caused by principal discharge area not at lowest elevation.	Lower the discharge to release storm flows and re-vegetate damaged areas.
Frequent operation of emergency spillway, long-term ponding and increased erosion potential caused by principal discharge point too small.	Consider increasing capacity of principal discharge, install supplemental discharge or install suitable erosion protection in emergency spillway.
Stormwater released from pond or basin too rapidly; caused by discharge.	Consider resizing discharge and add additional energy dissipation at discharge location.
Unsuccessful vegetation establishment.	Consider selecting plants that are native species tolerant of both wet and dry cycles and appropriate for the plant zone. Deep rooted perennials are encouraged to increase the rate of infiltration. Inspect plans to ensure they are properly planted and have correct soil conditions. Properly water them through establishment. Maintain plantings to make sure they are not taken over by noxious plants or weeds.