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Introduction

Background Erosion Information

When chemical, physical, and biological weathering take place, breaking down the underlying bedrock, soil is formed. It can take hundreds of thousands of years for one foot of soil to develop. Soil fertility, or the ability of soil to sustain life, is the product of a combination of the following properties: texture, structure, porosity and chemistry. If actions we take alter or destroy one of these properties, it may have serious adverse effects on the soil's ability to grow stabilizing vegetative cover.

After soil is formed, it is subject to erosion. Erosion is the detachment of soil particles from the surface. Erosion occurs naturally by the impact of raindrops, the flow of soil across the surface, or wind lifting soil particles. After the soil particles are removed from the surface, they are carried either a short or long distance, and then deposited on a new surface. This transport and deposition is called sedimentation.

Erosion and sedimentation occur naturally, but the actions of human beings change the rates of erosion. The global average, natural geological rater of soil erosion is about 0.2 tons per year. This rate of erosion is about equal to the rate at which soil is naturally created. Activities like construction, farming or logging, greatly increase the amount of sediment loss. Construction causes the greatest erosion increase. Soil from pastureland averages 1.5 tons per acre per year. Cropland can lose 20 tons per acre per year. Construction or mining sites can experience annual soil loss from 150 to 200 tons per acre. One millimeter or soil removed from an area of one acre weighs about five tons.

When sediment is deposited, it changes the flow characteristics of a water body. This could cause flooding, further erosion, and alteration of the hydrology of an area. Habitat for wildlife can also be altered or destroyed.

Not only is erosion a problem because of increased sedimentation, it is also a problem because of pollutants that may be carried in the sediment. This pollution could be in the form of metals, pesticides, or nutrients. Table 1 is a list of pollutants and their impacts on Water Quality.

Table 1: Pollutants and Their Impacts on Water Quality	
Pollutant	**Impacts on Water Quality**
Sediment	Sediment can be detrimental to aquatic life by interfering with photosynthesis, respiration, growth, reproduction, and oxygen exchange in water bodies. It can also transport other attached pollutants including nutrients, trace metals, and hydrocarbons.
Nutrients	Nutrients including nitrogen and phosphorous are the major plant nutrients used for fertilizing landscapes, and are often found in stormwater. If allowed to lodge in water bodies, these nutrients can result in excessive or accelerated growth of vegetation, such as algae, resulting in the impaired use of water in water bodies.
Bacteria and Viruses	Bacteria and viruses are common stormwater contaminants. Sources of these contaminants include animal excrement and sanitary sewer overflow. High levels of bacteria in stormwater have led to the closure of beaches, lakes and rivers to contact recreation.
Oil and Grease	Oil and grease are hydrocarbon compounds, some of which are toxic to aquatic organisms at low concentrations. Sources or oil and grease include leakage, spills, cleaning and sloughing associated with vehicle and equipment engines.
Metals	Common metals found in stormwater are lead, zinc, cadmium, copper, chromium, and nickel. Many artificial surfaces in an urban environment contain metal which enter stormwater as surfaces corrode, flake, dissolve, decay, or leach. Over half the trace metal in stormwater was carried there by sediment. Metals are toxic to aquatic organisms and have the potential to contaminate drinking water supplies.
Organics	When found in stormwater, organics are usually in low concentrations. Frequently synthetic organic compounds can be improperly stored, resulting in leakage into storm drains, etc.
Pesticides	Pesticides are often found in stormwater at toxic levels, even if they have been applied at levels consistent with the labels. Effects of these pesticides on the environment and human health are unknown.
Gross Pollutants	Gross pollutants are trash, debris and floatables that may include heavy metals, pesticides, and bacteria. They may create eye sores in waterways. They also include plant matter, animal excrement, and street litter. These substances may carry bacteria, viruses, and vectors, all of which could depress the dissolved oxygen levels in streams, lakes, and estuaries. This could cause fish kills.
Vector Production	Vector production (mosquitoes, flies and rodents) is frequently associated with sheltered habitats and standing water.

Storm Water Phase II Rule

The Storm Water Phase II Rule was published by the EPA on December 8, 1999. A copy of the regulatory text for construction sites is included as Appendix A in the appendices. This rule requires small Municipal Separate Storm Sewer Systems (MS4s) to develop and implement a stormwater management program which addresses the following six minimum control measures.

- Public education and outreach on stormwater impacts,
- Public Involvement/ participation in stormwater management,
- Illicit discharge detection and elimination,
- Construction site stormwater runoff,
- Post-construction stormwater management in new development and re-development, and

- Pollution prevention/good housekeeping for municipal operations.

Stormwater control has become increasingly difficult and important, mainly because of increased development. The problem has two main components: the increased volume of runoff, and the increased amount of pollutants in the runoff. The results of effective stormwater management are: the protection of wetlands, improved quality of receiving waterbodies, conservation of water resources, protection of public health, and flood control.

In the past, the main method of stormwater control has been treatment. This is a much more difficult and expensive way to try to control the effects of stormwater. Because of this, there is now increased emphasis on the prevention of degradation of the receiving water, instead of attempting to fix them once pollutants are present, or the physical structure and habitat have been altered. This is the focus of this manual.

Construction Sites

A great deal of the problem of erosion and sedimentation occur because of the increased impact caused by construction sites. Table 2 shows the most common sources of pollution on construction sites.

Table 2: Common Construction Site Pollutants

Construction Activity	Pollutants						
	Sediment	**Nutrients**	**Trace Metals**	**Pesticides**	**Oil, Grease, Fuels**	**Other Toxic Chemicals**	**Miscellaneous Waste**
Construction Practices							
Dewatering Operations	X					X	
Paving Operations	X			X	X	X	X
Structure Construction/Painting			X			X	X
Material Management							
Material Delivery and Storage	X	X	X	X	X	X	
Material Use		X	X	X	X	X	
Waste Management							
Solid Waste	X	X					X
Hazardous Waste						X	
Contaminated Spills	X					X	
Concrete Waste							X
Sanitary/Septic Waste							X
Vehicle/Equipment Management						X	X

Vehicle/Equipment Fueling						X	X
Vehicle/Equipment Maintenance						X	X

Purpose of This Manual

This manual is designed to assist construction operators and contractors choose appropriate BMPs to reduce stormwater runoff, erosion and sedimentation. It contains information about the correct way to compile and submit an erosion and sedimentation control plan, commonly called a stormwater pollution prevention plan (SWPPP), required by ordinance and as a part of the new Erosion and Sediment Control Ordinance and stormwater regulations. It also contains a section containing fact sheets about all the approved construction site BMPs for Casper, Wyoming. The appendices contain a copy of the EPA's Construction Site Stormwater Runoff Control Regulations, the erosion and sediment control inspection list, and the City of Casper Municipal Code, Chapter 12.20.

Glossary of Terms

Best Management Practices (BMPs)
Schedule of activities, prohibition of practices, maintenance procedures, and other management practices to prevent or reduce the discharge of pollutants to water sources. BMPs also include treatment requirements, operating procedures, and practice to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

Construction Activities
Any building activity disrupting more than one acre of land.

Erodibility
The susceptibility of a particular soil type to erosion by water or wind.

Erosion
Erosion is a three-step process involving the detachment, transportation, and deposition of soil particles. Land surface can be worn away by water, wind, ice or other geological agents. The five main types of erosion are sheet, rill, gully, stream bank, and wind.

Sheet Erosion
The uniform movement of a thin layer of soil across an expanse of land devoid of vegetative cover. Soil particles are detached by raindrops, which then go into runoff that is transported downstream to the point of deposition. This point of deposition occurs when runoff slows to the point where soil particles can no longer remain in suspension.

Rill Erosion
After sheet flows are concentrated on the land surface, rill erosion occurs. Rill erosion, as opposed to sheet erosion, leaves visible scouring on the landscape. This occurs when the duration or intensity of the rain increases, and runoff volumes and velocity accelerate.

Gully Erosion
Eventually, rill erosion becomes gully erosion as the rain continues to fall for long periods of time, or rainfall becomes more intensive. As this occurs, runoff volumes will accelerate, creating gullies. A gully is an area that has been scoured out to the point that it is not crossable with tilling or grading equipment.

Stream Bank Erosion
This type of erosion involves the scouring away of stream banks. Any degradation, or incising of streambeds and/or repeated high flows of extended duration cause this bank erosion. Any stream bank erosion is a significant contributor of sediment loads during high stream flows.

Wind Erosion
Wind erosion is similar to sheet erosion because detachment, transportation, and deposition of soil particles occurs. The difference is that instead of water, wind is the transportation mechanism. Sand size particles move in short hops close to the soil surface. Silt size particles move in longer hoops within 12 inches of the soil surface and clay size particles are lifted into suspension and moved into the air.

Erosion Control Measures
Erosion control measures are practices that slow or stop erosion. These methods are used in an attempt to prevent the detachment of soil particles and reducing the volume of runoff.

Final Stabilization
After the completion of all land disturbing activities, and the removal of all temporary sediment controls, vegetative cover is established on all exposed soil areas. Permanent roads are established and permanent stormwater best management practices are installed.

MS4s
Municipal Separate Storm Sewer Systems are known as MS4s. Large MS4s are cities serving populations of 100,000 or more, while small MS4s are cities serving less than 100,000.

Permanent Control
Permanent control is accomplished by the installation of land-surface cover, or erosion and sediment control measures that will remain in place for a long period of time.

Pollutant
Any material not usually found in water. These can include: dredged spoil solid waste, incinerator residue, filter backwash, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water.

Sedimentation
When solid materials, both inorganic (minerals) and organic, come to a rest on the earth's surface either above or below sea level, sedimentation occurs.

Sediment
Sediment is the detached soil particles moving in the erosion process that will settle or be deposited in a liquid under the force of gravity.

Sediment Control
Sediment control is trapping detached soil particles that are being transported and ensuring they are deposited on site to prevent damage to other properties or receiving waters.

Stormwater
Any water resulting from storms, snow melt runoff, and surface runoff and drainage.

Stormwater Pollution Prevention Plan (SWPPP)
A written document that describes the construction operator's activities to comply the with requirements of stormwater management. The SWPPP is intended to facilitate a process where the operator plans which BMPs will be used before construction is begun. A SWPP is sometimes called an Erosion and Sedimentation Control Plan.

Temporary
Installation of erosion or sediment control measures that are planned to be removed or inactivated after a period of time are considered temporary.

Erosion and Sedimentation Control Plans

Definition

An Erosion and Sedimentation Control Plan, also called a Stormwater Pollution Prevention Plan (SWPPP) is a document that identifies BMPs that will be implemented on a construction site in order to meet the requirements of the erosion and sediment control permits. These plans should be site specific, with each new construction site necessitating its own unique Erosion and Sedimentation Control Plan or SWPPP. The Erosion and Sediment Control Plan or SWPPP should be written before any construction activities begin on a site. The Erosion and Sedimentation Control Plan or SWPPP should be submitted to the City of Casper with the erosion and sediment control permit. After construction begins, a copy of the SWPPP should also be readily available on the site.

Purpose

An Erosion and Sedimentation Control Plan or SWPPP is required in order to reduce erosion and prevent sediment from leaving the construction site and therefore help in the protection of surface water quality. By planning which BMPs will be implemented before construction begins, the chances of runoff causing erosion or sediment loss, pollution, contamination or degradation are reduced. This will keep construction pollutants on site and out of surface waters. The basic idea is to create a plan to keep anything out of runoff that should not be there.

Requirements

For an Erosion and Sedimentation Control Plan or SWPPP to be effective, certain requirements must be met. These requirements are:

- Erosion and Sediment Control Plan Coordinator
- Site assessment and description
- Site map
- Estimates of the total area of the site that is expected to be disturbed
- A description of the construction activity
- Description of intended sequence of activities
- Pollutant assessment
- BMP selection
- BMP maintenance plan
- Certification by a licensed civil engineer that BMPs are sufficient
- Employee Certification

These requirements to an Erosion and Sedimentation Control Plan or SWPPP make the planning of a construction site a clear, step-by-step process.

Erosion and Sediment Control Plan Coordinator

This should be the name and contact information of the persons ultimately responsible for implementing the Erosion and Sediment Control Plan. This can be an individual or a team.

Site Assessment and Description

The following questions should be answered in this section:

- What is the topography? The steeper the terrain, the more difficult the planning process.
- How much vegetative cover exists on the site? A lot or very little? Where is it located? Always maintain as much vegetation as possible during construction.
- What will the sources of runoff be? Will these sources be disturbed in construction operations? How much runoff will there be? Select BMPs to match volume and velocity of expected flows.
- Are there any water bodies on the site, or immediately downstream? Where are they located?

Site Map

Any submitted maps must be understandable, with clearly identified erosion controls and pollutant sources. Maps should also note drainage patterns, soils, vegetation, surface water bodies, and steep or unstable slopes. While these maps do not have to be certified or professionally drafted, they must demonstrate clear planning on the site. They should have an appropriate scale, and information should be readily retrievable. It is acceptable to submit multiple maps.

Estimate of Disturbed Area

Answer the following questions in this section.

- What is the total area of the site that is expected to be disturbed by excavation?
- What is the amount of disturbance? Will it be disturbed in phase clearing, or minimized clearing?

Construction Activity Description

Answer the following question in this section.

- What is the nature of the activity? Include equipment storage, cleaning and maintenance areas and activities; points of ingress and egress to the construction site; material loading, unloading, and storage practice and areas, including construction materials, building materials and waste materials; and materials, equipment, or vehicles that may come in contact with stormwater

Activities Sequence

The following questions should be answered in this section.

- What is the description of the intended sequence of major activities which disturb soil for major portions of the site? Major activities shall include but are not limited to all excavation and backfill operations, as well as grading operations.
- What are the anticipated starting and completion time periods of the site grading and/or construction sequence, including the installation and removal time periods of erosion and sediment control measures, and the time of exposure of each area prior to the completion of temporary erosion and sediment control measures?

Pollutant Assessment

Answer the following questions in this section.

- What type of pollutants could result from this construction activity? Sediment, fuel, herbicides, paint, used oil, concrete washout, etc.?
- Are there any non-sediment pollutants? If so, what are they?

A description of pollutants can be found on Table 1 in the introduction

BMP Selection

- Select the BMPs to be used to match the pollutant identified above. Include a description of when and how best management practices shall be incorporated into the work. Technical specifications of the BMPs, materials, and resources shall be provided with the Erosion and Sediment Control Plan.
- When listing chosen BMPs, list both structural and non-structural. These BMPs can be listed in bullet, table or phase form, with a clear description accompanying them. Be sure to list BMPs used for planning, the major construction activities, and all post-construction activities.
- Describe other precautions that will be taken to prevent pollution. These controls can include sediment tracking, fuel storage and handling, sanitary wastes, trash handling, and any other controls for pollutants that may be brought onto the site.
- Plan your project with storm water control in mind. When planning, it is important to minimize exposure, ensure physical space for BMPs, and incorporate the BMPs into other construction activities where possible. Plan how often BMPs will be inspected for maintenance needs. Also consider the cost, not only of implementation but also on-going maintenance costs.
- A basic guide of how to select which BMPs to utilize follows in the introduction to the BMP fact sheets.

BMP Maintenance Plan

- This section should describe procedures that will be used to inspect and maintain all the BMPs previously identified in the Erosion and Sedimentation Control Plan.
- A sample inspection checklist is included in the Appendices and Appendix C.

Civil Engineer Certification
Certification by a licensed civil engineer that the best management practices proposed for the disturbed area shall be sufficient to reduce erosion and control sediment for all disturbed areas one (1) acre (not necessarily contiguous) or greater in size is required.

Employee Certification
This section is a signature page that should contain the following statement, followed by a signature and date.

> I certify under penalty of law that this document and all attachments were prepared under my direct supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

During Construction

After construction begins, it is vital that the prepared plan be followed. The controls must be implemented, and after implementation, the BMPs must be inspected and maintained according to the written schedule in the Erosion and Sedimentation Control Plan. If any changes in the plan occur, notify the City of Casper.

Post-Construction/Final Stabilization

A report should be made to the City of Casper upon final stabilization of the construction site. At this time, and after inspection, the sediment and erosion control bond will be released.

BMP Fact Sheets

Classification of BMPs

There are two main classifications of BMPs listed in this manual. The first type are **erosion prevention practices.** These BMPs are ground covers that prevent any type of erosion from occurring. Erosion prevention BMPs listed in this manual include:

- Preservation of Existing Vegetation
- Temporary Seeding
- Permanent Seeding and Planting
- Sod Stabilization
- Mulch
- Geotextiles
- Soil Retention Measures
- Chemical Stabilizers
- Stream Bank Stabilizers
- Dust Control

The second type of BMP listed in this manual are **sediment control practices.** These BMPs are an attempt to prevent soil particles that are already being carried in stormwater from leaving the construction sites and entering water bodies. Sediment control BMPs listed in this manual include:

- Stormwater Outlet Protection
- Stormwater Inlet Protection
- Diversion Swale/Berms
- Sediment Basins
- Silt Fencing
- Erosion Control Fencing
- Stabilized Construction Entrance/Exits
- Street Sweeping

While the BMPs listed serve mainly their primary purpose as above categorized, most of them serve both purposes simultaneously. None of these BMPs are designed as stand alone practices except in very limited circumstances. On the whole, it is important to plan to install multiple BMPs to reduce erosion and trap as much sediment as possible.

Selection of BMPs

The three steps to BMP selection are:

- Define BMP objectives
- Identify BMP categories
- Select appropriate BMPs

Define BMPs

Selection of which BMPs must be employed ought to be based on the pollution risks associated with the construction activity in use. The site assessment must be examined to discover the pollutants that need to be guarded against, and therefore which of the following objectives must be met.

- Minimize disturbed areas – The only land that should be cleared is land that will be actively under construction in the near term (6-12 months). Maintain as much vegetation as possible during the rainy season, and avoid clearing sensitive areas (e.g., steep slopes and natural watercourses). Do not clear areas where construction will not occur. High wind areas should be especially protected in late fall and winter when winds are at their worst.
- Stabilize disturbed areas – Areas of the site that must be disturbed should be temporarily stabilized whenever active construction is not taking place on the site. Permanent stabilization should be provided during the finish grade and landscaping.
- Protect slopes and channels – Safely convey runoff from the top of the slope and stabilize disturbed slopes as soon as possible. Avoid disturbing natural channels if at all possible. Ensure that any increases in runoff velocity caused by the project do not erode existing channels.
- Control site perimeter – Safely divert stream runoff around or through the construction project. Always follow local regulation as to the process of diverting runoff. Any runoff that does leave the project site should be free of excessive sediment and other pollutants. All entrances/exits should be tracked to control sediment leaving the site.
- Retain sediment – Retain all sediment-laden waters from disturbed active areas within the site.

Identify BMP Categories

After the objectives of the BMPs have been defined, identify the category of BMP best suited to meet these objectives on each specific site, with its own individual conditions, construction activities and cost considerations. The two categories as discussed above are erosion prevention practices and sediment control practices.

Select BMPs

A combination of the BMP objectives and BMP categories leads to a selection of specific BMPs appropriate fro each individual site condition, construction activity, and cost. In most cases, various BMPs are needed at different times during construction.

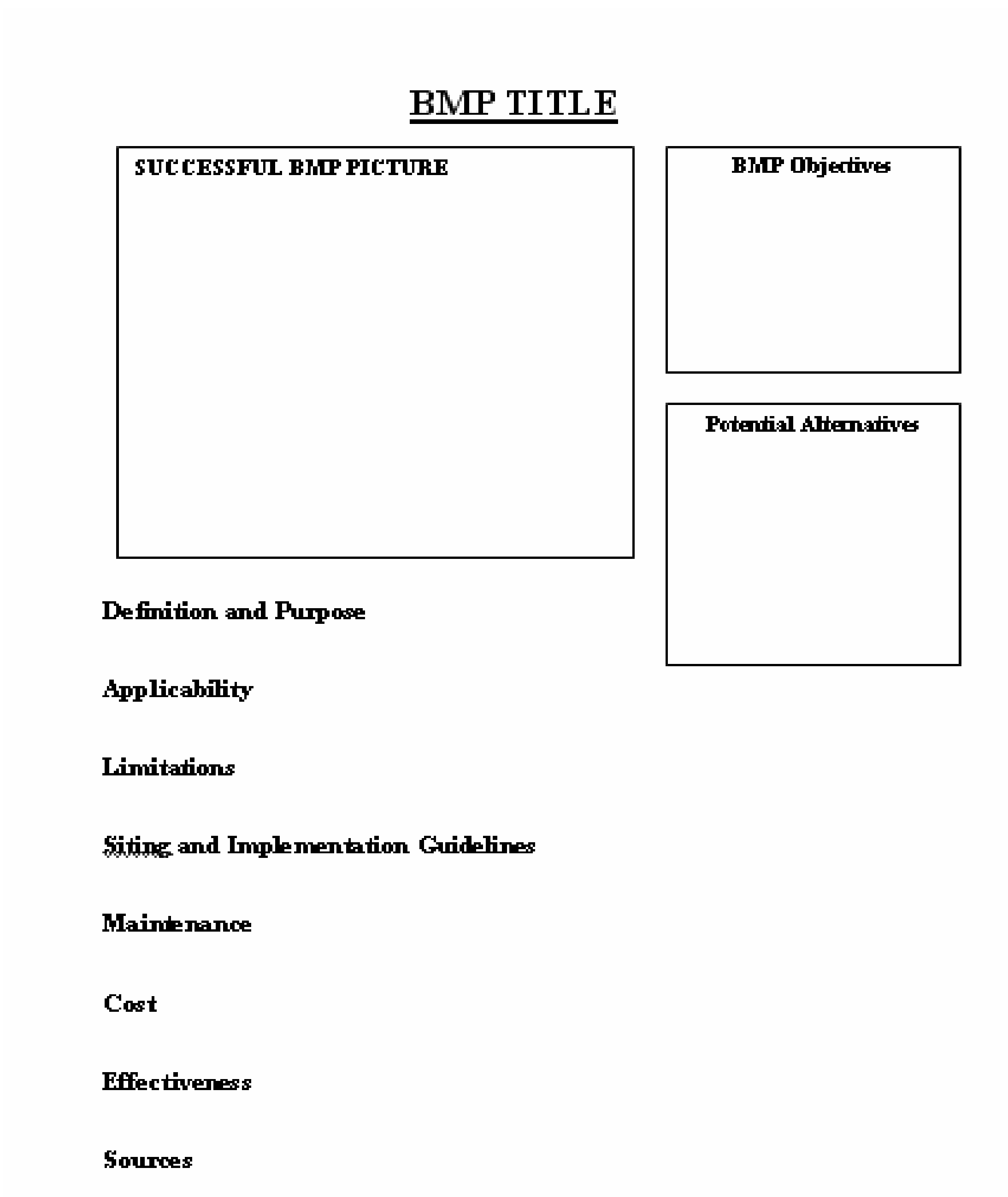
Table 1: Basic BMP Selection Guidelines		
BMP Name	**Primary Purpose**	**Erosion Processes**
Preservation of Existing Vegetation	Protection of desirable vegetation by limiting soil detachment	All
Temporary Seeding	Provide soil protection through new plant growth	All
Permanent Seeding and Planting	Provide soil protection through new plant growth	All
Sod Stabilization	Provide soil protection through new plant growth	All
Mulching	Protection of disturbed soil with mulch to limiting soil detachment	Sheet, Rill, Gully, Wind, and Snow Melt
Geotextiles	Protect disturbed soil or slopes	All
Soil Retention Measures	Provides detention and retention of sediment	Sheet, Wind, and Snow Melt
Chemical Stabilizers	Protection of disturbed soil with stabilizers to limit soil detachment	Sheet, Rill, Gully, Wind, and Snow Melt
Stormwater Outlet Protection	Prevent scour of exiting stormwater flows	Stream Bank, Snow Melt, and Shoreline
Stormwater Inlet Protection	Intercept sediment at curb inlets. Should be used in conjunction with other on-site techniques	Stream Bank and Snow Melt
Stream Bank Stabilization	Protection of disturbed soil to limit soil detachment and sedimentation	Stream Bank, Snow Melt, and Gully
Diversion Swale/Berm	Intercept, divert, and convey surface run-on	Stream Bank, Sheet, Rill, Gully, and Snow Melt
Sediment Basin	Provides controlled outflow which allows sediment to settle out of runoff	Stream Bank, Snow Melt, Sheet, Rill, and Gully
Silt Fencing	Slow and filter runoff to retain sediment	Stream Bank, Wind, Snow, Shoreline and Sheet
Erosion Control Fencing	Slow and filter wind and sand to retain sediment	Wind and Snow Melt
Stabilized Construction Entrance/Exit	Reduces offsite sediment tracking from trucks and construction equipment	Special
Dust Control	Provides minor detention of sediment	Wind
Street Sweeping	Prevent sediment from entering waterway	Stream Bank and Wind

BMP Maintenance

The main maintenance action as listed on each fact sheet is regular inspections. These inspections enable you to identify where improvements must be made. A sample inspection sheet can be found in the Appendices as Appendix B.

BMP Fact Sheets

Figure 1 is a template of the BMP Fact Sheets presented in this manual. These fact sheets are not meant to be all inclusive, but a starting point for implementation.


BMP TITLE

SUCCESSFUL BMP PICTURE

BMP Objectives

Potential Alternatives

Definition and Purpose

Applicability

Limitations

Siting and Implementation Guidelines

Maintenance

Cost

Effectiveness

Sources

Figure 1: BMP Fact Sheet Template

Preservation of Natural Vegetation

BMP Objectives
- Erosion control
- Sediment control
- Soil stabilization
- Minimize damage to existing trees and other vegetation
- Aesthetic value
- Permanent control measure

Potential Alternatives
- None

Definition and Purpose

Carefully planned **preservation of existing vegetation** is one of the most effective methods of erosion control and stormwater management. By paying attention to what vegetation is necessary to remove, and what can be feasibly saved, natural buffer zones are created. This is a permanent control measure. Some benefits are the protection of desirable trees and vegetation from damage during development, erosion control, stormwater detention, biofiltration, velocity dissipation, and aesthetic value. Other benefits of this BMP occur because natural vegetation:

- Can process higher quantities of stormwater runoff than newly seeded areas,
- Does not require time to establish,
- Has a higher filtering capacity than newly planted vegetation because of the denser vegetation,
- Reduces stormwater runoff by intercepting rainfall, promoting infiltration, and lowering the water table,
- Provides buffers and screens against noise and visual disturbance,
- Provides a fully developed habitat for wildlife,
- Usually requires less maintenance than planting new vegetation, and
- Enhances aesthetics.

Applicability

Preservation of natural vegetation is applicable to all construction sites with pre-existing vegetation. Only land needed for building activities and vehicle traffic needs to be cleared. This BMP can be particularly useful on large sites, and the following:

- Areas within the site where no construction will occur, or is currently occurring. By utilizing planning, these sites can be identified and protected.
- In wetlands, floodplains, stream banks, steep slopes and other areas where erosion controls would be difficult to establish, install, or maintain.
- Areas where local, state, and federal governments require the preservation of vegetation. These areas are usually designated in the original plans.
- Areas where vegetation may eventually need to be removed, but can be used currently as an erosion and sediment control.
- Used to maintain pre-construction drainage patterns to avoid vegetation die off as a result of water flows being intercepted and diverted away from the existing vegetation.

Limitations

- The amount of vegetation existing in preconstruction conditions limits the use of this BMP.
- Preserving vegetation requires planning.
- Preservation is limited by the size of the site relative to the size of the structures to be built.
- High land costs may reduce the cost effectiveness of this practice.
- Equipment must have enough room to maneuver.
- Improper grading of a site might result in changes in environmental conditions that result in vegetative dieoff.

Siting and Implementation Guidelines

- Mark vegetation for preservation before clearing begins. Use of orange colored plastic mesh fencing is encouraged.
- Prepare a site map with the location of trees and boundaries of environmentally sensitive areas and buffer zones to be preserved. This should be included in your SWPPP.
- Plan the location of roads, buildings and other structures in order to avoid vegetated areas.
- Follow the natural contours and maintain preconstruction drainage patterns.
- Do not nail boards to trees during building operations.
- Do not cut tree roots inside the tree drip line.
- Use barriers to prevent the approach of equipment within protected areas.
- Remove barriers around preserved areas during final site cleanup.
- No toxic or construction materials should be stored within 50 feet of the drip line, nor should they be disposed of in any way which would injure vegetation.

When selecting trees for preservation, consider the following factors:

- *Tree vigor.* Preserving healthy trees that will be less susceptible to damage, disease, and insects. Indicators of poor vigor include dead tips of branches, stunted leaf growth, sparse foliage, and pale foliage color. Hollow, rotten, split, cracked, or leaning trees also have less chance of survival.
- *Tree age.* Older trees are more aesthetically pleasing as long as they are healthy.
- *Tree species.* Species well-suited to present and future site conditions should be chosen. Preserving a mixture of evergreens and hardwoods can help to conserve energy when evergreens are preserved on the northern side of the site to protect against cold winter winds and deciduous trees are preserved on the southern side to provide shade in the summer and sunshine in the winter.
- *Wildlife benefits.* Trees that are preferred by wildlife for food, cover, and nesting should be chosen.

Maintenance

- Inspections should be performed regularly, especially during construction.
- If damage to the vegetation occurs, it should be repaired or replaced immediately to maintain the integrity of the natural system.
- Serious tree injuries shall be attended to by an arborist.
- Ensure that protected areas are not adversely impacted by new structures.
- Newly planted vegetation should be planned to enhance the existing vegetation.
- Do not leave tree roots exposed to air. (See Figure 1)

Figure 1: Tree Root Exposure

Cost

The main potential cost associated with preservation of natural vegetation is the increased labor that might be required to maneuver around trees or protected areas. Other possible costs are likely less than the cost of applying other erosion and sediment controls to the disturbed areas. Replacement of vegetation inadvertently destroyed during construction can be extremely expensive, sometimes in excess of $10,000 per tree.

Effectiveness

Natural vegetation is very effective in providing water quality benefits by intercepting rainfall, filtering stormwater runoff, and preventing off-site transport of sediments and other pollutants. It is one of the most effective methods of erosion and sediment control.

Sources

- Picture Source: U.S. Environmental Protection Agency, National Pollutant Discharge Elimination System (NPDES), "Construction Site Storm Water Runoff Control: Preserving Natural Vegetation", http://cfpub.epa.gov/npdes/stormwater/menuofbmps/site_24.cfm
- Figure 1 Source: J.M. Sillick and W.R. Jacobi. "Healthy Roots and Healthy Trees." Colorado State University. June, 2004. http://www.ext.colostate.edu/pubs/garden/02926.html
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Temporary Seeding

BMP Objectives

- Sediment containment
- Soil stabilization
- Wind erosion control

Potential Alternatives

- Erosion Seeding
- Permanent Seeding
- Mulching
- Geotextiles
- Preservation of natural vegetation

Definition and Purpose

Vegetative cover is one of the most effective methods of erosion control and sediment containment. **Temporary seeding** is the establishment of a temporary vegetative cover for areas with a slope of 3:1 or flatter that will be exposed longer than 14 days or will be further disturbed at a later date. This BMP is designed to prevent the migration of soil down a slope due to construction disturbances.

Applicability

Temporary seeding can be used on areas needing temporary protection that will eventually require permanent vegetation at the completion of the construction project. It is also appropriate for areas that will be re-disturbed after a long period of inactivity. This BMP provides quick erosion protection for disturbed areas. Once the vegetation as been established, it traps sediment, promotes infiltration, and improves site appearance. It is a relatively inexpensive method of erosion control.

Limitations

- Temporary seeding may not be appropriate in dry areas or areas without supplemental irrigation.
- Areas with continual construction traffic will not be able to maintail viable vegetative growth.
- Temporary seeding must have sufficient time to be established.
- Additional mulching may be necessary to protect seeding during the weeks before true establishment of vegetation

- Steep slopes are not to be temporarily seeded.
- Seeding may require fertilizer on poor quality soils.
- Temporary seeding is not appropriate for short-term inactivity (less than 14 days).

Siting and Implementation Guidelines

- Soil type and site conditions should govern seed selection design.
- If soil is compacted, it should be disked, plowed, tilled or scarified to provide seed lodgement.
- Do not seed between November 15 and February 15, or between July 1 and August 15, unless irrigated by a sprinkler system. Base further seeding time decisions on moisture content of the soil and weather conditions.
- Type 1 seeds should be used in disturbed areas where no native vegetation exists. The mixture of seed should not contain more than 0.5 percent weed, 0.5 percent crop seed, and 6.0 percent inert matter. Figure 1 shows names of type 1 seed and their planting specifications.

Table 1: Type 1 Seeds and Planting Specifications

Name of Seed	Percentage Seed by Weight	Minimum Germination
Kenblue Kentucky Bluegrass	20%	80%
Kentucky Bluegrass (various varieties)	30%	75%
Creeping Red Fescue (various varieties)	30%	85%
Perennial Ryegrass (various varieties)	20%	90%

- Vegetate in spring or fall with type 2 seed for areas with native vegetation, suggestions including:

  - Spike Wheatgrass (Critona)
  - Slender Wheatgrass (Pryor or Revenue)
  - Western Wheatgrass
  - Stream Bank Wheatgrass
  - Bozoisky Wild Rye
  - Hairy or Sweet Vetch
  - Fairway Crested Wheatgrass
  - Other blends and species available.

- Apply all seeds at a rate of 12-16 pounds per acre (hydroseeding), or 30-32 pounds per acre (broadcast).
- Seed slopes should be 3:1 or flatter.
- Following the application, roughen the slopes with furrows along the contours to a depth 1-2 inches below grade.
- To enhance plant establishment, mulching is strongly recommended in addition to temporary seeding. Mulch will keep the seeds in place and moderate soil temperature and moisture until the seeds germinate.

- Follow-up application should be made to cover spots of poor germination as necessary to maintain adequate soil protection.

Maintenance

- Inspect seed areas for failures, re-seeded and mulched within the planting season. If germination does not occur, they must be re-seeded to provide appropriate cover.
- After rainfall, inspection must be made to ensure continued seed and vegetative cover.
- Seed rows are most efficient when they are planted perpendicular to the prevailing wind direction.

Cost

Table 2: Suggested Seeds and Their Average Prices

Seed Species	Price Range ($/ Lb Pure Live Seed)
Kenblue Kentucky Bluegrass	$1.25-1.40
Kentucky Bluegrass (various varieties)	$1.25-2.75
Creeping Red Fescue (various varieties)	$1.25-1.50
Perennial Ryegrass (various varieties)	$1.15-1.40
Thick Spike Wheatgrass (Critona)	$2.00-2.50
Slender Wheatgrass (Prior or Revenue)	$1.40-2.77
Western Wheatgrass (Rosanna or Arriba)	$2.80-3.30
Stream Bank Wheatgrass (Sodar)	$1.75-3.46
Bozoisky Wild Rye	$1.75-2.43
Hairy Vetch	$1.25-1.50
Fairway Crested Wheatgrass	$1.15-1.82

Effectiveness

This is an inexpensive method of erosion control. After the initial effort of seeding and germination, temporary seeding needs only minimal inspection to ensure continued viability. A well-established vegetative cover is one of the best erosion controls available, and is nature's own method of erosion control.

Sources

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- *City of Casper Standard Specifications for Public Works Construction and Infrastructure Improvements.* Sections 203.02, "Restoration of Lawn and Grassed Areas," and 203.03, "Seed Specifications." December, 2001. Adopted by Ordinance 5-02.
- Wind River Seed, Manderson, Wyoming. www.windriverseed.com
- Granite Seed, Lehi, Utah. www.graniteseed.com

Permanent Seeding and Planting

BMP Objectives

- Soil stabilization
- Wind erosion control
- Reduce stormwater runoff velocity
- Promote infiltration
- Improve wildlife habitat
- Improve aesthetics
- Provide permanent stabilization

Definition and Purpose

Potential Alternatives

- Temporary seeding
- Preservation of natural vegetation
- Geotextiles
- Erosion seeding
- Mulching

Permanent seeding is the planting of perennial vegetation such as trees, shrubs, vines, grasses, or legumes on exposed areas for final permanent stabilization. This is done in order to provide stabilization to the soil by holding soil particles in place. It also serves to reduce stormwater runoff velocity, maintain sheet flow, protect the soil surface from erosion, promote infiltration of runoff into the soil, improve wildlife habitat, and improve the aesthetics of a construction area. This BMP is: economical because of lower initial costs and labor inputs; adaptable to different site conditions; and allows selection of the most appropriate plant materials.

Applicability

Permanent seeding is appropriate where permanent, long-lived vegetative cover is the most practical, or most effective method of stabilizing the soil. It will work best in areas that are roughly graded, and will not be re-graded for at least a year. Other areas include filter strips, buffer areas, vegetated swales, steep slopes and stream banks. It is also very effective on areas where soils are unstable because of their texture, structure, a high water table, high winds or a high slope. Vegetation will grow most efficiently in areas where the topsoil was never stripped, or where it has been returned and incorporated into the soil surface.

Limitations

- There is a high erosion potential during establishment of vegetative cover.
- Areas that fail to establish growth will need to be reseeded.
- Seeding times are limited depending on the season.
- Vegetative growth needs stable soil temperature and soil moisture content during germination and early growth.
- Permanent seeding does not immediately stabilize soils so they may require other temporary erosion and sediment control methods.
- Establishing vegetation may require irrigation.
- Success depends initially on climate and weather.

Siting and Implementation Guidelines

Planning guidelines

- When stripping a site, topsoil should be stockpiled for later use. According to City of Casper Municipal Code Chapter 12.20.065, "the height of soil piles for residential construction shall not exceed four feet in height. In all cases soil piles shall be controlled by best management practices to control erosion and sediment from leaving the construction site whether by wind erosion or erosion by precipitation." This stabilization of stockpiles can be accomplished by the use of temporary seeding.
- Plan to plant when soil and weather conditions are most favorable for growth.
- Where a suitable planting medium is not present, topsoil should be imported and incorporated.
- Select appropriate vegetation.
- After planting, apply straw mulch in the amount of 2 tons per acre.

Distinguish future use

- Permanently seeded areas can be considered high- or low- maintenance areas.
- **High-maintenance** areas are mowed frequently, limed and fertilized regularly, and either receive intense use (e.g., athletic fields) or require maintenance to an aesthetic standard (e.g., home lawns).
  - Select grasses for high-maintenance areas that are long-lived perennials that form a tight sod and are fine-leaved.
  - High-maintenance vegetative cover is used for homes, industrial parks, schools, churches, and recreational areas.
- **Low-maintenance** areas are mowed infrequently or not at all, and do not receive lime or fertilizer on a regular basis.
  - Plants must be able to persist with minimal maintenance over long periods of time. Grass and legume mixtures are favored for these sites because legumes fix nitrogen from the atmosphere.
  - Suitable sites include steep slopes, stream or channel banks, some commercial properties, and "utility" turf areas such as road banks.

Grading and Shaping

- Grading and shaping may not be required where hydraulic seeding and fertilizing equipment is to be used.
- Overlot grading will often bring to the surface subsoils that have low nutrient value, little organic matter content, few soil microorganisms, rooting restrictions, and conditions less conducive to infiltration of precipitation.
- Vertical banks should be sloped to enable plant establishment.
- Grade and shape the slope so that equipment can be used safely and efficiently during seedbed preparation, seeding, mulching and maintenance of the vegetation.
- Concentrations of water that could cause excessive soil erosion should be diverted to a safe outlet.

Topsoil

- Topsoil should be friable and loamy, free of debris, objectionable weeds and stones, and contain no toxic substances that may be harmful to plant growth.
- Soil pH should be between 6.0 and 6.5 and can be increased with liming if soils are too acidic.
- Topsoil should be handled only when it is dry enough to work without damaging soil structure.
- A uniform application of 5 inches (unsettled) is recommended, but may be adjusted.

Table 1: Cubic Yards of Topsoil Required to Attain Various Soil Depths

Depth of Topsoil (Inches)	Volume Topsoil Per 1,000 Square Feet	Volume Topsoil per Acre
1	3.1	134
2	6.2	268
3	9.3	403
4	12.4	537
5	15.5	672
6	18.6	806

Seedbed Preparation

- The surface soil must be loose enough for water infiltration and root penetration.
- Tillage at a minimum should loosen the soil to a depth of 4 to 6 inches; alleviate compaction; incorporate topsoil, lime, and fertilizer; smooth and firm the soil; allow for the proper placement of seed, sprigs, or plants; and allow for the anchoring of straw or hay mulch if a crimper is to be used.
- Apply fertilizer in an amount to result in 40 pounds of available nitrogen per acre.

Maintenance

- Grasses should emerge within 4-28 days and legumes 5-28 days after seeding.

- A successful area should exhibit:
  - Vigorous dark green or bluish green seedlings, not yellow
  - Uniform density, with nurse plants, legumes and grasses well intermixed
  - Green leaves
- Inspection of the seeding application should be regularly performed.
- Reseed or replace areas that have eroded.
- If an area has inadequate cover, the choice of plant materials and quantities of lime and fertilizer should be reevaluated.
- Consider seeding temporary, annual species if the season is not appropriate for permanent seeding.
- If vegetation continually fails to grow, soil should be tested to determine if low pH or nutrient imbalances are responsible.

Cost

Seeding costs range from $200 to $1,000 per acre and average $400 per acre. Maintenance costs range from 15 to 25 percent of initial costs and average 20 percent. See “Table 2: Suggested Seeds and Their Average Prices” in the Temporary Seeding Section on page 22.

Effectiveness

Perennial vegetative cover from seeding has been shown to remove between 50 and 100 percent of total suspended solids from stormwater runoff, with an average removal of 90 percent.

Sources

- Picture Source: Sedspec: Sediment and Erosion Control Planning, Design and SPECification Information and Guidance Tool website. http://pasture.ecn.purdue.edu/~sedspec/sedspec/perl/maintenance.pl?structure=perm_seeding#
- U.S. Environmental Protection Agency National Pollutant Discharge Elimination System (NPDES) website, “Construction Site Storm Water Runoff Control: Permanent Seeding.” http://cfpub.epa.gov/npdes/stormwater/menuofbmps/site_23.cfm
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Sod Stabilization

BMP Objectives
- Sediment control
- Erosion control
- Establish immediate ground cover
- Reduce stormwater runoff
- Increase water infiltration
- Improve aesthetics

Potential Alternatives
- Permanent vegetation
- Preserving existing vegetation

Definition and Purpose

Sodding is a permanent vegetative cover used as an erosion control practice. It involves laying grass sod on exposed soils for stabilization. In addition to soil stabilization, sodding reduces the velocity of stormwater runoff, provides immediate cover for critical areas, and stabilizes areas that cannot be seeded. Another important use is stabilization of channels or swales that convey concentrated flows.

Applicability

Sodding can be used on any graded or cleared area that needs immediate cover to protect from erosion, and a permanent plant cover is needed immediately. Prime locations for sodding are buffer zones, stream banks and other waterways, drop inlets, dikes, swales, steeply sloped areas, outlets, level spreaders, filter strips, and residential or commercial lawns and golf courses where prompt use and aesthetics are important.

Limitations

- Sod is more expensive than seed, and it is more difficult to obtain, transport and store.
- Soil preparation must be done carefully.

- Adequate moisture must be provided before, during and after installation for successful establishment.
- If sod is not adequately irrigated after installation, root dieback may occur because grass does not root rapidly and is subject to drying out.

Siting and Implementation Guidelines

Soil Preparation

- Fine-grade soil surface before laying down the sod.
- Clear surface of trash, woody debris, stones and clods larger than 1 inch.
- Soils should be tested to determine if amendments are needed.
- If topsoil is removed, it should be replaced to a maximum of 1 foot. Do not lay sod on less than 4 inches of topsoil.

Installation

- Sod should be harvested, delivered, and installed within a period of 36 hours.
- Sod can be laid during times of the year when seeded grasses are likely to fail.
- Do not plant sod during very hot or wet weather.
- Sod should not be placed on slopes greater than 3:1 if they are to be mowed.
- Sod should be laid in strips perpendicular to the direction of water-flow as shown in Figure 1 on the Diagrams page at the end of this worksheet.
- Lay sod in a staggered, brick-like pattern, as shown in Figure 2 on the Diagrams page.
- Don’t overlap joints.
- Firmly staple the corners and middle of each strip, as shown in Figure 3. When ready to mow, drive stakes or staples flush with the ground.
- Jute or plastic netting may be pegged over the sod for further protection against washout during establishment.
- Roll, then irrigate sod and the top 4 inches of soil immediately after installation.
- Water sod frequently within the first few weeks of installation

Materials

- Sod used should be certified.
- Type of sod selected should be composed of plants adapted to site conditions.
- Sod composition should reflect both environmental conditions and future site uses.
- Sod should be machine cut at a uniform soil thickness of 15 to 25 mm at the time of establishment.
- Sod should be cut to the desired size. Do not use torn or uneven pads.

Maintenance

- Inspect sod frequently, especially after large storm events. The appearance of good sod is shown in Figure 4 on the Diagrams page.
- Remove and replace dead sod.

- Mow new sod sparingly; mowing should not result in the removal of more than one-third of the shoot.
- Grass height should not be cut to less than 2-3 inches.

Cost

Construction sodding averages between \$0.20 per square foot and range from \$0.10 to \$1.10 per square foot; maintenance costs are approximately 5 percent of installation costs.

Effectiveness

Studies show that sod removes up to 99 percent of total suspended solids in runoff. This makes it a highly effective management practice for erosion and sediment control. The trapping efficiency, however, is highly variable depending on hydrologic, hydraulic, vegetation, and sediment characteristics.

Sources

- Picture Source: Brumfield Sod Farm Website. http://www.brumfieldsod.com/installation.htm
- Figures 1-5 Source: *Tennessee Erosion and Sediment Control Handbook*, Tennessee Department of Environment and Conservation. "Disturbed Area Stabilization (With Sod) Fact-Sheet", 2002. www.state.tn.us/environment/wpc/sed_ero_controlhandbook/
- National Pollutant Discharge Elimination System (NPDES) website, "Construction Site Storm Water Runoff Control: Sodding." http://cfpub.epa.gov/npdes/stormwater/menuofbmps/site_31.cfm
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Diagrams

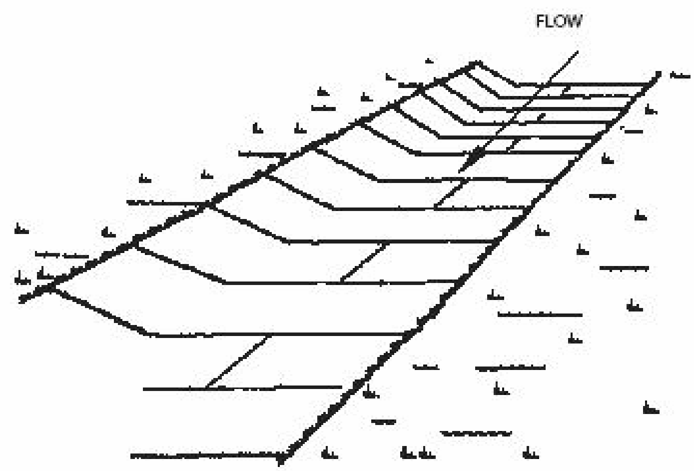

Figure 1: Strip Direction

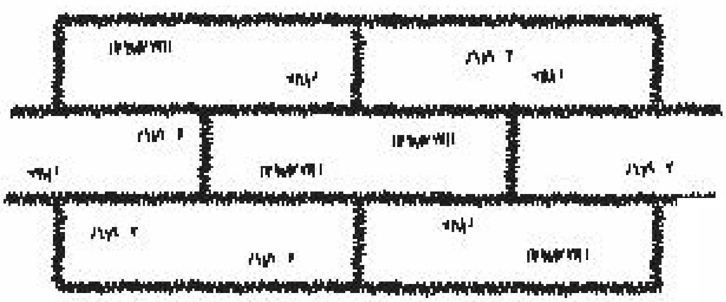

Figure 2: Sod Pattern

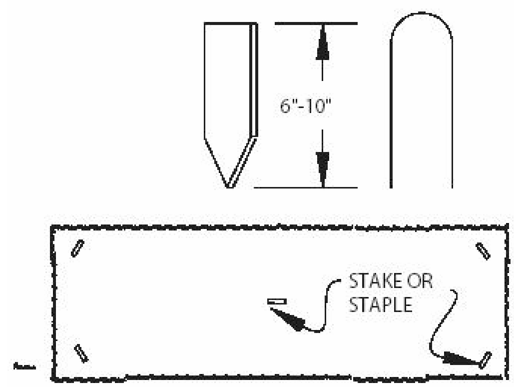

Figure 3: Staple and Stake Pattern

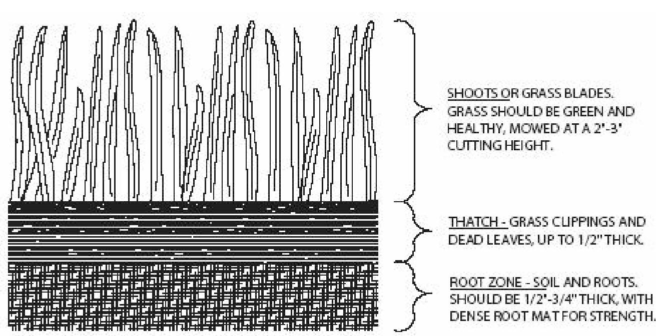

Figure 4: Appearance of Good Sod

Mulching

BMP Objectives
- Soil stabilization
- Erosion control
- Wind erosion control
- Sediment control
- Moisture retention
- Promote seed germination
- Prevent surface compaction
- Modify soil temperature

Potential Alternatives
- Hydroseeding
- Soil binders
- Geotextiles
- Temporary seeding
- Chemical stabilization

Definition and Purpose

Mulching is a temporary erosion control practice which involves the spread of organic materials over exposed or recently planted soil surfaces. If possible, the mulch should consist of materials produced on site. Benefits resulting from mulching are wide ranging. Not only does the spread of mulch prevent erosion and stabilize soils, it also aids in plant growth by holding seeds, fertilizers and topsoil in place, prevents birds from eating the seeds, helps retain moisture, and insulates against extreme temperatures. There are three main types of mulching.

Straw mulch- Straw mulch consists of placing a uniform layer of straw and incorporating it into the soil with a studded roller or anchoring it with a tackifier. Straw mulch protects the soil surface from the impact of rain drops, which prevents soil particles from being dislodged.

Wood mulch- Wood mulch consists of applying a mixture of shredded wood, bark or compost to exposed soil surfaces. Wood mulch is mostly applicable to landscape projects. The main function of wood mulching is to reduce erosion by protecting bare soil from rainfall impact, increasing infiltration, and reducing runoff.

Hydraulic mulch- Hydraulic mulch consists of applying a mixture of small cellulose fibers made from shredded wood or recycled paper, and a stabilizing emulsion or tackifier with hydro-mulching equipment. This mixture temporarily protects exposed soil from erosion by raindrop impact or wind. It also provides protection and warmth for seed growth.

Applicability

Mulching can best be used in areas in need of immediate, effective and inexpensive erosion control. It is often used in areas where temporary seeding cannot be used because of environmental constraints. It can also be used to promote vegetation germination and growth during a vegetative stabilization practice, especially where slopes are steeper than 2:1 or where sensitive seedlings require insulation from extreme temperatures or moisture retention.

Straw mulch- Straw mulch is most applicable in combination with temporary and/or permanent seeding strategies to enhance plant establishment.

Wood mulch- Wood mulch is most applicable as a stand-alone, short term ground cover on slopes. It is a useful cover until soils can be prepared for revegetation.

Hydraulic mulch- Hydraulic mulch is most useful in conjunction with temporary seeding practices. Use of hydraulic mulch should be avoided where the mulch would be incompatible with immediate earthwork activities and would have to be removed.

Limitations

- Mulching may delay seed germination as the cover reduces the soil surface temperatures.
- The mulch cover is subject to erosion, and may be washed away in a large storm.
- Close inspections and maintenance are necessary to ensure effective erosion control.

Straw mulch

- Availability of straw and straw blowing equipment may be limited just prior to rainy seasons or storms due to high demand.
- There is a potential for introduction of weed seed and unwanted plant material.
- Wind may limit application of straw and blow straw into undesired locations.
- When straw blowers are used to apply straw mulch, the treatment areas must be within 45m (150 ft) of a road or surface capable of supporting trucks.
- Straw mulch applied by hand is more time intensive and potentially costly.
- Mulching may have to be removed prior to permanent seeding or soil stabilization.
- "Punching" of straw does not work on sandy surfaces.

Wood mulch

- Wood mulch is not suitable for use on slopes steeper than 3:1. It is best suited to flat areas or gentle slopes or 5:1 or flatter.

- Green material has the potential for the presence of unwanted weeds and other plant materials.
- Shredded wood does not withstand concentrated flows and is prone to sheet erosion.
- Delivery system is primarily by manual labor, although pneumatic application equipment is available.
- Wood mulch may need to be removed prior to further earthwork.

Hydraulic mulch

- Wood fiber hydraulic mulches area generally short-lived, and often require a second application in order to remain effective for an entire rainy season.
- Hydraulic mulch needs 24 hours to dry before a rainfall occurs to be effective.

Siting and Implementation Guidelines

Site preparation

- Grade site to enable the use of equipment for applying and anchoring mulch.
- Install best management practices as required, such as sediment barriers and diversions.
- Loosen compacted soil to a minimum depth of 4 inches if using mulch while seeding.

Installation

- Organic mulches should be used for erosion control and plant material establishment.
- All materials should be free of seed. (See Table 1 for specifics)
- There must be adequate cover to prevent erosion, washout, and poor plant establishment.
- When anchoring mulch, press straw into soil immediately after the mulch is spread. Serrated discs are preferred and should be 20 inches or more in diameter and 8 to 10 inches apart.

Straw mulch

- Roughen embankments and fill rills before placing the straw mulch by rolling with a crimping or punching type roller or by track walking.
- The straw mulch must be evenly distributed on the soil surface.
- Avoid placing straw onto the traveled way, sidewalks, lined drainage channels, sound walls, and existing vegetation.
- Use a tackifier to hold straw in place. A tackifier acts to glue the straw fibers together and to hold the soil surface. The tackifier shall be selected based on longevity and ability to hold the fibers in place.
- A tackifier is typically applied at a rate of 140 kg/ha (125 lbs/ac). In windy conditions, the rates are typically 200 kg/ha (175 lbs/ac).

Wood mulch

- Remove existing vegetation.
- Roughen embankment and fill areas by rolling with a device such as a punching type roller or by track walking.
- Apply by hand, or pneumatic methods where available.
- Evenly distribute on a site to a depth of 2-3 inches.

Hydraulic mulch

- Roughen embankment and fill areas by rolling with a crimping or punching type roller.
- Hydraulic mulch requires 24 hours drying time to be effective.
- Avoid mulch over spray onto roads, sidewalks, drainage channels, existing vegetation, etc.
- Paper based hydraulic mulches alone should not be used for erosion control.

Table 1: Mulching Materials and Application Rates

Material	Rate per Acre	Requirements	Notes
Straw	1-2 tons	Dry, unchopped, unweathered; avoid weeds.	Spread by hand or machine; must be tacked or tied down.
Hydraulic wood fiber or cellulose	½- 1 ton		Do not use in hot, dry weather. Requires 24 hours to dry.
Wood Chips	5-6 tons	Air dry. Add fertilizer, 12 lb/ton.	Apply with blower, chip handler, or by hand. Not for fine turf areas.
Bark	35 yd^3	Air dry, shredded, or hammermilled, or chips.	Apply with mulch blower, chip handler, or by hand. Do not use asphalt tack.

Maintenance

- Mulches must be anchored to resist wind displacement.
- Mulched areas should be inspected frequently to identify areas where mulch has loosened or been removed, especially after rain storms.
- Faulty or removed mulch should be replaced immediately.

Cost

Straw mulch- Average annual cost for installation and maintenance (3-4 months useful life) is $2,500 per acre. Application by hand is more time intensive and potentially costly.

Wood mulch- Average annual cost for installation and maintenance (3-4 months useful life) is around $4,000 per acre, but cost can increase if the source is not close to the project site.

Hydraulic mulch- Average cost for installation of wood fiber hydraulic mulch is $900 per acre.

Effectiveness

Soil loss reduction for:

- Straw mulch ranges from 89.3 to 93.2 percent.
- Wood mulch ranges from 28.8 to 93.6 percent.
- Hydraulic mulch ranges from 85.9 to 99.1 percent.

Water velocity reductions range from 24 to 78 percent.

Sources

- Picture Source: Pickaway Soil and Water Conservation District (SWCD) Streambank Stabilization Photos, http://pickaway.oh.nacdnet.org/pictures/streambank_stabilization/01.jpg
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Geotextiles

BMP Objectives
- Erosion Control
- Wind Erosion Control
- Sediment Control
- Moisture Regulation

Potential Alternatives
- Hydraulic Mulch
- Chemical Stabilization
- Straw Mulch
- Wood Mulch

Definition and Purpose

Geotextiles are also known as filter fabrics, road rugs, synthetic fabrics, construction fabrics, or fabrics. They are a porous fabric manufactured from synthetic materials. These fabrics are designed to reduce erosion from rainfall impact, hold soil in place, and absorb and hold moisture near the soil surface. It can also be used to secure mulching to the ground, and stabilize soil while other plants are growing.

Applicability

Geotextiles can be used on any surface where the erosion hazard is high. They are frequently used on steep slopes, areas where mulch must be anchored, and areas waiting for vegetation. This BMP is designed to be an immediate and temporary protection, such as when stock piles of soil are left overnight. Once the geotextiles have been properly installed, they can prevent the migration of soil, protect growing plants, and hold mulching in place.

Limitations

- Geotextiles have the potential of being sensitive to light and must be protected prior to installation.
- Some types might promote increased runoff.
- When they are no longer being used, geotextiles must be disposed of in a landfill.

- Blankets and mats are more expensive than other erosion control measures, due to labor and material costs. This limits their use to areas inaccessible to hydraulic equipment, or where other measures are not applicable.
- They are not suitable for excessively rocky sites.
- Plastic sheeting can be easily torn.
- Installation is critical and requires experienced contractors.
- Geotextiles are not suitable for areas with heavy foot traffic.

Siting and Implementation Guidelines

Preparation

- Material selection should be based on specific type of application and site conditions.
- The selected fabric should match its purpose.
- The following criteria are helpful in the selection of the appropriate material:
    - Cost
        - Material cost
        - Preparation cost
        - Installation cost
        - Add-ons
    - Effectiveness
        - Reduction of erosion
        - Reduction of flow velocity
        - Reduction of runoff
    - Acceptability
        - Environmental compatibility
        - Institutional/regulatory acceptability
        - Visual impact
    - Vegetation Enhancement
        - Native plant compatibility
        - Moisture retention
        - Temperature modification
        - Open space/coverage
    - Installation
        - Durability
        - Longevity
        - Ease of installation
        - Safety
    - Operation and Maintenance
        - Maintenance frequency
- Proper site preparation is essential to ensure complete contact of the blanket or mat with the soil. If there is no contact, the material will not hold the soil, and erosion will occur underneath the material.

Anchoring

- Lay and secure fabric according to manufacturer's instructions.
- Use U-shaped wire staples, metal geotextile stake pins, or triangular wooden stakes to anchor geotextiles to the ground surface.
- Use U-shaped wire staples a minimum of 11 gauge steel wire with 8 inch legs and a 2 inch crown.
- Metal stake pins should be 0.188 inch diameter steel with a 1.5 inch steel washer at the head of the pin, and 8 inches in length.
- Drive staples and metal stakes flush to the soil surface.

Installation (See Figure 1 on Diagram page)

- Begin at the top of the slope and anchor blanket in a 6 inch deep by 6 inch wide trench. Backfill trench and ramp earth firmly.
- Unroll blanket downhill.
- Overlap edges 2 to 3 inches and staple every 3 feet.
- Lay blankets loosely and maintain direct contact with soil. Do not stretch.

Maintenance

- Trapped sediment should be removed after each storm event.
- All blankets and mats should be inspected periodically after installation. Any problems discovered should be repaired immediately. Failure to repair holes results in spot erosion, as shown in Figure 2 to the right.
- Patch damaged portions with fabric overlapping on all sides a minimum of 1 foot.
- Installation shall be inspected after significant rainstorms to check for erosion and undermining. Any failures shall be repaired immediately.
- When no longer required for the work, temporary soil stabilization shall be properly disposed.
- Make sure matting is uniformly in contact with the soil.

Figure 2: Failure to Repair

Cost

The costs are relatively high in comparison with other BMPs. Biodegradable materials range from \$0.50-\$0.57/yd^{2}. Permanent materials range from \$3.00-\$4.50/yd^2. Staples range from \$0.04-\$0.05/staple.

Table 1: Approximate Costs for Installed Geotextile Materials		
Rolled Erosion Control Products		**Installed Cost per Acre**
Biodegradable	Jute Mesh	$6,500
	Curled Wood Fiber	$10,500
	Straw	$8,900
	Wood Fiber	$8,900
	Coconut Fiber	$13,000
	Coconut Fiber Mesh	$31,200
	Straw Coconut Fiber	$10,900
Non-Biodegradable	Plastic Netting	$2,000
	Plastic Mesh	$3,200
	Synthetic Fiber with Netting	$34,800
	Bonded Synthetic Fibers	$50,000
	Combination with Biodegradable	$32,000

Effectiveness

Geotextiles' effectiveness depends upon the strength of the fabric and proper installation. If properly installed, they can be a very effective erosion control mechanism.

Sources

- Picture Source: U.S. Environmental Protection Agency National Pollutant Discharge Elimination System (NPDES) website, "Construction Site Storm Water Runoff Control: Geotextiles" http://cfpub.epa.gov/npdes/stormwater/menuofbmps/site_14.cfm
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Diagrams

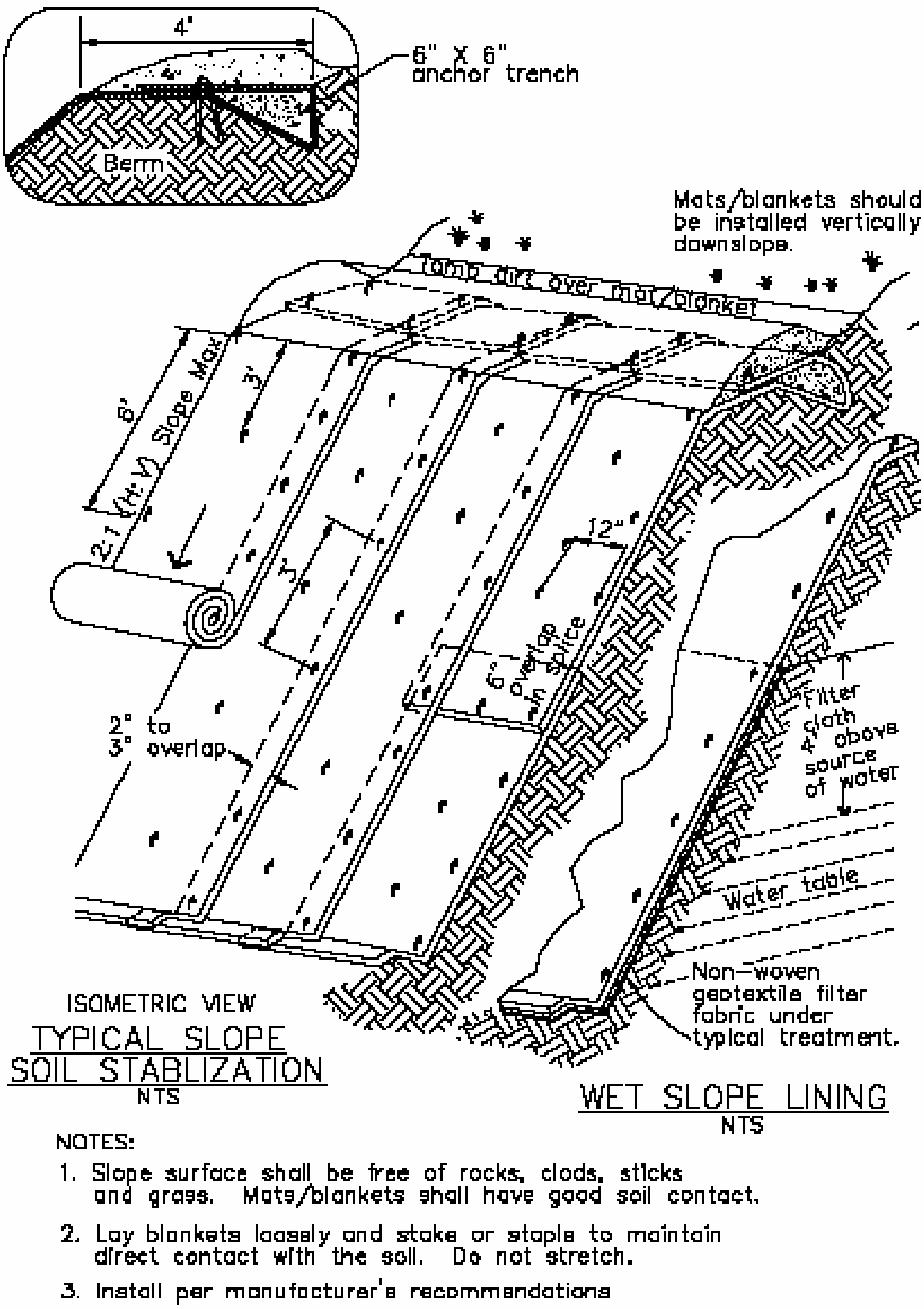

Figure 1: Typical Installation Details

Soil Retention Measures

BMP Objectives
- Erosion control
- Wind erosion control
- Soil stabilization
- Worker protection

Potential Alternatives
- Mulching
- Temporary seeding
- Geotextiles

Definition and Purpose

Soil retention measures are structures or practices used to hold soil in place or to keep it contained within a site boundary. The two main methods of soil retention that will be examined in this fact sheet are structural methods (mainly retaining walls,) and soil binders. Retaining walls are methods of erosion control and also a method of protecting workers from falling or sliding dirt during a construction project. Soil binders consist of applying and maintaining polymeric or lignin sulfonate soil stabilizers or emulsions. They are materials temporarily applied to a soil surface to prevent water and wind erosion during the duration of construction.

Applicability

Reinforced soil-retaining structures such as retaining walls and grading should be used when sites have very steep slopes or loose, highly erodible soils that cause other methods, such as chemical or vegetative stabilization or regarding, to be ineffective. The preconstruction drainage pattern should be maintained to the extent possible.

Soil binders are applied to disturbed areas requiring short-term protection. Because soil binders can often be incorporated into the earth work, they may be a good choice for areas where grading activities will soon resume. Soil binders are also very suitable for use on stockpiles.

Limitations

Structural methods

- Soil retention structures must be designed to handle expected loads.
- Heavy rains or mass wasting may damage or destroy these structures and result in sediment inputs to waterbodies.

Soil binders

- Soil binders are temporary in nature and may need reapplication.
- Soil binders require a minimum curing time as prescribed by the manufacturer, which may be 24 hours or longer until fully effective.
- Soil binders will generally experience spot failures during heavy rainfall events. If runoff penetrates the soil at the top of a slope treated with a soil binder, it is likely that the runoff will undercut the stabilized soil layer and discharge at a point further down slope.
- They do not hold up to pedestrian or vehicular traffic across treated areas.
- Soil surfaces made primarily of silt and clay may not be penetrated by soil binders, particularly when compacted.
- If low temperatures occur within 24 hours of application, soil binders may not cure.
- The water quality impacts of soil binders are relatively unknown and some may have water quality impacts due to their chemical impacts.

Siting and Implementation Guidelines

Structural methods

- To ensure safety of the retaining structure, it should be designed by a qualified engineer who understands all of the design considerations, such as the nature of the soil, location of the ground water table, and the expected loads.
- Take care to ensure that the hydraulic pressure does not build up behind the retaining structure and cause failure.
- Examples of the reinforcing soil retaining structures include:
- *Skeleton sheeting*. This is an inexpensive soil bracing system that requires soil to be cohesive and consists of construction grade lumber being used to support the excavated face of a slope.
- *Continuous sheeting*. This method involves using a material that covers the entire slope continuously, with struts and boards placed along the slope to support the slope face- steel, concrete, or wood are the appropriate materials. An example of a continuous sheeting retaining wall is shown in Figure 1.

Figure 1

- *Permanent retaining walls.* Walls of concrete masonry or wood (usually railroad ties) that are left in place after construction is complete in order to provide continued support of the slope. An example of a permanent retaining wall is shown in Figure 2.

Figure 2

Soil binders

- Soil type will dictate which soil binder is appropriate to use.
- A soil binder must be environmentally benign, easy to apply, easy to maintain, economical, and shall not stain paved or painted surfaces.
- Avoid over-spray onto the traveled way, sidewalks, lined drainage channels, and existing vegetation.

<u>Selecting a soil binder</u>

- Properties of common soil binders used for erosion control are provided on Table 1. This should be used to select an appropriate binder.

Table 1: Properties of Soil Binders for Erosion Control

Evaluation Criteria	Binder Type			
	Plant Material Based (Short Lived)	Plant Material Based (Long Lived)	Polymeric Emulsion Blends	Cementitious-Based Binders
Relative Cost	Low	Low	Low	Low
Resistance to Leaching	High	High	Low to Moderate	Moderate
Resistance to Abrasion	Moderate	Low	Moderate to High	Moderate to High
Longevity	Short to Medium	Medium	Medium to Long	Medium
Minimum Curing Time Before Rain	9 to 18 hours	19 to 24 hours	0 to 24 hours	4 to 8 hours
Compatibility with Existing Vegetation	Good	Poor	Poor	Poor
Mode of Degradation	Biodegradable	Biodegradable	Photodegradable/ Chemically Degradable	Photodegradable/ Chemically Degradable
Labor Intensive	No	No	No	No
Specialized Application Equipment	Water Truck or Hydraulic Mulcher	Water Truck or Hydraulic Mulcher	Water Truck or Hydraulic Mulcher	Water Truck or Hydraulic Mulcher
Liquid/Powder	Powder	Liquid	Liquid/Powder	Powder

Surface Crusting	Yes, but dissolves on rewetting	Yes	Yes, but dissolves on rewetting	Yes
Clean Up	Water	Water	Water	Water
Erosion Control Application Rate	Varies	Varies	Varies	4,000 to 12,000 lbs/acre

- *Soil types and surface materials*- Fines and moisture content are key properties of surface materials. Consider a soil binder's ability to penetrate, likelihood of leaching, and ability to form a surface crust on the surface materials.
- *Frequency of application*- The frequency of application can be affected by subgrade conditions, surface type, climate, and maintenance schedule. Frequent applications could lead to high costs. Application frequency may be minimized if the soil binder has good penetration, low evaporation, and good longevity.
- Examples of plant material based (short lived) binders are Guar, Psyllium, and Starch.
- Examples of plant material based (long lived) binders are Pitch and Rosin Emulsion.
- Examples of Polymeric Emulsion Blend Binders are Acrylic Copolymers, Liquid Polymers of Methacrylates and Acrylates, Copolymers of Sodium Acrylates and Acrylamides, Poly-Acrylamide and Copolymer of Acrylamide, and Hydro-Colloid Polymers.
- The main Cementitious-based binder is Gypsum.

Applying Soil Binders

- Follow manufacturer's written recommendations for application rates, pre-wetting of application area, and cleaning of equipment after use.
- Prior to application, roughen embankment and fill areas.
- Consider the drying time for the selected soil binder and apply with sufficient time before anticipated rainfall.

Maintenance

Structural methods

- Inspect structures periodically, particularly after rainstorms.
- Repair any damage immediately, prior to any reinstallation of the materials.

Soil binders

- Inspect high traffic areas on a daily basis and lower traffic areas on a weekly basis.
- Reapply the selected soil binder as needed for proper maintenance.

Cost

Structural methods

These structures can be expensive because they require a professional engineer to develop a design (estimate to be 25 to 30 percent of construction costs.) Capital costs include mobilization, grading, grooving, tracking and compacting fill, and installing the structures.

Soil binders

Table 2: Approximate Costs for Soil Binders	
Soil Binder	**Cost per Acre**
Plant-Material Based (Short Lived) Binders	$400
Plant-Material Based (Long Lived) Binders	$1,200
Polymeric Emulsion Blend Binders	$400
Cementitious-Based Binders	$800

Effectiveness

If properly designed and installed, these methods can effectively prevent erosion and mass wasting in areas with steep slopes and erodible soils.

Sources

- Picture Source: U.S. Environmental Protection Agency, National Pollutant Discharge Elimination System (NPDES), "Construction Site Storm Water Runoff Control: Soil Retention", http://cfpub.epa.gov/npdes/stormwater/menuofbmps/site_32.cfm
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Chemical Stabilization

BMP Objectives
- Reduce erosion
- Improve settling of suspended sediment
- Soil stabilization
- Wind erosion control
- Dust control

Potential Alternatives
- Temporary seeding
- Mulching
- Sod stabilization measures
- Soil retention measures
- Geotextiles

Definition and Purpose

Chemical stabilizers provide temporary soil stabilization to disturbed soils. Also known as soil binders or soil palliatives, materials made of vinyl, asphalt, or rubber ore sprayed onto the surface of exposed soils to hold the soil in place and protect against erosion from runoff and wind.

Applicability

Chemical stabilization can be used in areas where other stabilization methods such as seeding and vegetation are not effective because of environmental constraints. They can be used on:

- Rough graded soils that will be inactive for a period of time,
- Final graded soils before application of final stabilization,
- Temporary haul roads prior to placement of crushed rock surfacing,
- Compacted soil road base,
- Construction staging, materials storage, and layout areas,
- Soil stockpiles, and
- Areas that will be mulched.

They can also be applied to stormwater as it enters sediment basins. This will cause soil particles to bind together and settle within the pond.

Chemical stabilization should be used in combination with other BMPs, such as vegetative or perimeter controls.

Limitations

- Chemical stabilizers can create impervious surfaces where water cannot infiltrate, increasing the rate of storm water runoff.
- Overuse of these stabilizers may adversely affect water quality.
- Chemical stabilization is usually more expensive than vegetative practices.
- Experience with chemical stabilizers is much more limited than with vegetative BMPs.
- Chemical stabilizers shall not be applied directly to water, or a slope flowing directly into a water body without passing through a sediment trap or basin.
- These stabilizers are usually more expensive than vegetative practices.

Siting and Implementation Guidelines

- Chemical stabilizers are available in emulsions, powders, and gel bars or logs.
- The application rates and procedures recommended by the manufacturer of a chemical stabilization product should be followed as closely as possible to prevent the product from forming ponds and to avoid creating impervious areas where storm water cannot infiltrate.
- Chemical stabilizers should be used in conjunction with, not in place of other BMPs.
- Stormwater runoff from chemically stabilized soil should pass through a sediment control BMP prior to discharging to surface waters.
- The use of silt fences should be maximized in chemically stabilized areas.

Maintenance

- Chemically stabilized areas should be regularly inspected for signs of erosion. Stabilizers should be reapplied if necessary.
- Stabilizers should be reapplied on actively worked areas after a 48-hour period.
- If chemically stabilized soil is left undisturbed a reapplication may be necessary after two months.
- More applications may be needed for steep slopes, silty and clayey soils, long grades and high precipitation areas.

Cost

Polyacrylamide, one of the more common soil palliatives, costs between $4.00 and $35.00 per pound; a pound can stabilize approximately one acre of land.

Effectiveness

Effectiveness ranges from 70 to 90 percent, varying by the type of chemical stabilization method used. Effectiveness of each individual stabilizer type depends on soil type, application method, and individual chemical characteristics of the polymer.

Sources

- Picture Source: U.S. Environmental Protection Agency, National Pollutant Discharge Elimination System (NPDES), "Construction Site Storm Water Runoff Control: Chemical Stabilization", http://cfpub.epa.gov/npdes/stormwater/menuofbmps/site_42.cfm
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Stormwater Outlet Protection

BMP Objectives
- Soil stabilization
- Sediment control
- Erosion control
- Prevent scour
- Reduce water flow speed

Potential Alternatives
- None

Definition and Purpose

Stormwater outlet protection devices are structurally lined aprons or other acceptable energy dissipating devices placed at the outlets of pipes or paved channel sections. These methods prevent scour at stormwater outlets and minimize the potential for downstream erosion by reducing the velocity of concentrated stormwater flows. Outlet protection can be achieved through a variety of techniques, including stone or riprap, concrete aprons, paved sections and settling basins installed below the storm drain outlet.

Applicability

Outlet protection should be installed at all pipe, interceptor dike, swale or channel section outlets where the velocity of flow may cause erosion at the pipe outlet and in the receiving channel, or to all storm drain outlets in a construction site. It should also be used at outlets where the velocity of flow at the design capacity may result in plunge pools.

Limitations

- Outlet protection may be unsightly.
- This may cause sediment removal problems, necessitating removal of the outlet structure itself.
- Frequent maintenance may be required for rock outlets with high velocity flows.
- Loose rock may be washed away during high flows.
- Grouted riprap may break up in areas of freeze and thaw.

Siting and Implementation Guidelines

- Install riprap, grouted riprap, or concrete apron at selected outlet. Riprap aprons are best suited during construction. Figure 1 on the Diagram page shows general construction of riprap outlet protection.
- For proper operation of apron:
  - Align apron with receiving stream such that a straight line is created. If a curve is needed to fit site conditions, place it in upper section of apron.
  - If size of apron riprap is large, protect underlying filter fabric with a gravel blanket.
- Outlets on slopes steeper than 10 percent shall have additional protection.

Maintenance

- Inspect temporary measures prior to predicted storm events, and as soon as possible after storm events, and regularly (approximately once per week) during the construction season.
- Inspect apron for displacement of dissipation devices and/or damage to the underlying fabric and repair as needed.
- Inspect for scour beneath the dissipation devices and around the outlet. Repair damage to slopes or underlying filter fabric immediately.
- Temporary devices shall be completely removed as soon as the surrounding drainage area has been stabilized, or at the completion of construction.

Cost

Stormwater outlet protection measures range in cost from $3 per square yard to $60 per square yard. Alternatives range from grass ($3-7), sod ($$8-12) and concrete ($25-30), to riprap (nongrouted; $35-50, grouted; $45-60).

Effectiveness

When properly designed and installed, these measures can prevent virtually all erosion from the protected area.

Sources

- Picture Source: *Tennessee Erosion and Sediment Control Handbook*, Tennessee Department of Environment and Conservation. "Storm Drain Outlet Protection Fact-Sheet", 2002. www.state.tn.us/environment/wpc/sed_ero_controlhandbook/
- Figure 1 Source: *Tennessee Erosion and Sediment Control Handbook*, Tennessee Department of Environment and Conservation. "Storm Drain Outlet Protection Fact-Sheet", 2002. www.state.tn.us/environment/wpc/sed_ero_controlhandbook/

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Diagrams

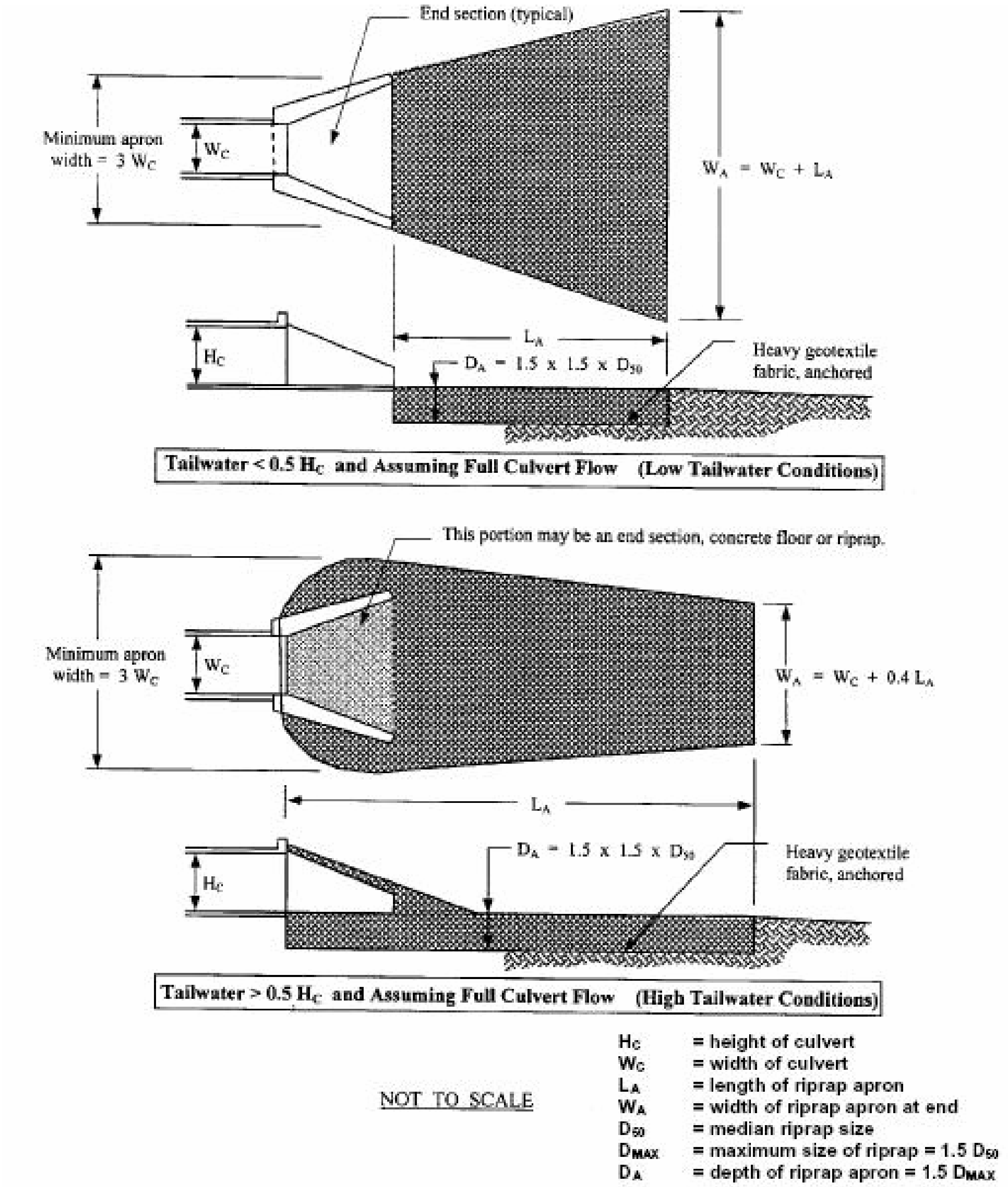

Figure 1: Riprap Outlet Protection Construction Design

Stormwater Inlet Protection

BMP Objectives

- Sediment control
- Litter Control

Potential Alternatives

- Silt Fencing
- Fiber rolls
- Sandbag barrier

Definition and Purpose

Storm drain inlet protection are controls that help prevent soil and debris from site erosion from entering storm drain drop inlets. These methods usually consist of a sediment filter or an impounding area around or upstream of a storm drain, drop inlet, or curb inlet. These filtering devices allow stormwater to flow into the drain, but only after excess sediment has been filtered out. This is an advantageous practice because their use allows storm drains to be used during even the early stages of construction.

Three temporary control methods of inlet protection are:

- Excavation around the perimeter of the drop inlet, which creates a settling pool to remove sediments. Next, weep holes protected by gravel are used to drain the shallow pool of water that accumulates around the inlet.
- Fabric barriers made of porous materials around inlet entrances can create an effective shield to erosion sediment while allowing water flow into the storm drain. This method is demonstrated in the above picture
- Block and gravel inlet protection uses standard concrete blocks and gravel to form a barrier to sediments while permitting water runoff through select blocks laid sideways. This method is demonstrated in Figure 1.

Figure 1

Applicability

Every storm drain receiving sediment-laden runoff should be protected. Excavated drop inlet protection and block and gravel inlet protection are applicable to areas of high flow where overflow is anticipated into the storm drain. These are appropriate where ponding will not encroach onto highway traffic. Fabric barriers are recommended for smaller, relatively flat drainage areas (slopes less than 5 percent leading to the storm drain.) Storm drain inlet protection is most necessary during wet and snow-melt seasons.

Limitations

- Stormwater drop inlet protection measures should not be used as stand-alone sediment control measures.
- Temporary storm drain inlet protection is not intended for use in drainage areas larger than 1 acre.
- These protection measures are practical for relatively low-sediment, low-volume flows.
- If sediment and other debris clog the water intake, drop intake control measures can actually cause erosion in unprotected areas.
- Inlet protection should only be used when ponding will not encroach into highway traffic or onto erodible surfaces and slopes.
- Frequent maintenance is required.
- Filter fabric fence inlet protection is appropriate in open areas is subject to sheet flow and for flows not exceeding 0.014 m^3/s ($0.5ft^3/s$).
- Excavated drop inlet sediment traps are appropriate where relatively heavy flows are expected and overflow capability is needed.

Siting and Implementation Guidelines

General

- These controls should be installed before any soil disturbance in the drainage area.
- Do not place filter fabric underneath the inlet grate since the collected sediment may fall into the drain inlet when the fabric is removed or replaced.
- At a minimum, use 0.5 inch wire mesh screen or filter fabric covered with rock or commercially available products to cover the storm drain inlet to filter out trash debris and sediment.

Excavation around drop inlet (See Figure 2 on Diagrams page)

- Install filter fabric fence in accordance with following instructions.
- Dig a minimum of 1 foot deep (2 feet maximum) with a minimum excavated volume of 35 yd^3 per acre disturbed.
- Side slopes leading to the inlet should be no steeper than 1:1.
- The shape of the excavated area should be designed such that the dimensions fit the area from which stormwater is anticipated to drain. For example, the longest side of

an excavated area should be along the side of the inlet expected to drain to the largest area.

Filter Fabric Fences (See Figure 3 on Diagrams page)

- The filter fence should be staked close to the inlet to prevent overflow on unprotected soils.
- Excavate a trench approximately 6 inches wide and 6 inches deep along the line of the silt fence inlet protection device.
- Place 2 inches by 2 inches wooden stakes around the perimeter of the inlet a maximum of 3 feet apart and drive them at least 18 inches into the ground or 12 inches below the bottom of the trench. The stakes must be at least 48 inches.
- Lay fabric along bottom of trench, up side of trench, and then up stakes. The maximum silt fence height around the inlet is 24 inches.
- Staple the filter fabric to wooden stakes. Use heavy-duty wire staples at least 1 inch in length.
- Backfill the trench with gravel or compacted earth all the way around.
- The top of the frame and fabric should be below the down-slope ground elevation to prevent runoff bypassing the inlet.

Block and Gravel Inlet Protection (See Figure 4 on Diagrams page)

- Place hardware cloth or comparable wire mesh with 0.5 inch openings over the drop inlet so that the wire extends a minimum of 1foot beyond each side of the inlet structure. If more than one strip is necessary, overlap the strips. Place filter fabric over the wire mesh.
- Place concrete blocks lengthwise on their sides in a single row around the perimeter of the inlet, so that the open ends face outward, not upward. The ends of adjacent blocks should abut. The height of the barrier can be varied, depending on design needs, by stacking combinations of blocks that are 4 inches, 8 inches, and 12 inches wide. The row of blocks should be at least 12 inches but no greater than 24 inches high.
- Place wire mesh over the outside vertical face (open end) of the concrete blocks to prevent stone from being washed through the blocks. Use hardware cloth or comparable wire mesh with a 0.5 inch opening.
- Pile washed stone against the wire mesh to the top of the blocks. Use 0.75 to 3 inch.

Maintenance

- Do not allow sediment to wash into the storm drain inlet.
- When the contributing drainage area has been permanently stabilized, all materials and any sediment should be removed, and either salvaged or disposed of properly within 30 days.
- When done with construction, bring area to a proper grade, then smooth and compact area around storm drain.
- Inspect inlet protection devices before and after a storm.

- **Excavation around drop inlet**- Remove accumulated sediment when the excavated area reaches 50 percent capacity. Weep holes in excavated areas around inlets can become clogged and prevent water from draining out of shallow pools that form. Should this happen, unclogging the water intake may be difficult and costly.
- **Filter Fabric Fences**- If the fabric becomes clogged, torn or degraded, it should be replaced. Make sure the stakes are securely driven in the ground and are in good shape (i.e., not bent, cracked or splintered, and are reasonably perpendicular to the ground). Replace damaged stakes.
- **Block and gravel inlet protection**- If the gravel becomes clogged with sediment, it must be carefully removed from the inlet and either cleaned or replaced. Since cleaning gravel at a construction site may be difficult, consider using the sediment-laden stove as fill material and put fresh stone around the inlet. Inspect bags for holes, gashes, and snags, and replace bags as needed. Check gravel bags for proper arrangement and displacement.

Cost

The average annual cost of a storm drain inlet protection device is $200 per inlet, including installation and maintenance. The frequent maintenance can be very expensive.

Effectiveness

Excavated drop inlet protection may be used to improve the effectiveness and reliability of other sediment traps and barriers, such as fabric or block and gravel inlet protection. However, as a whole, the effectiveness of inlet protection is low for erosion and sediment control, long-term pollutant removal, and low for habitat and stream protection.

Sources

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Diagrams

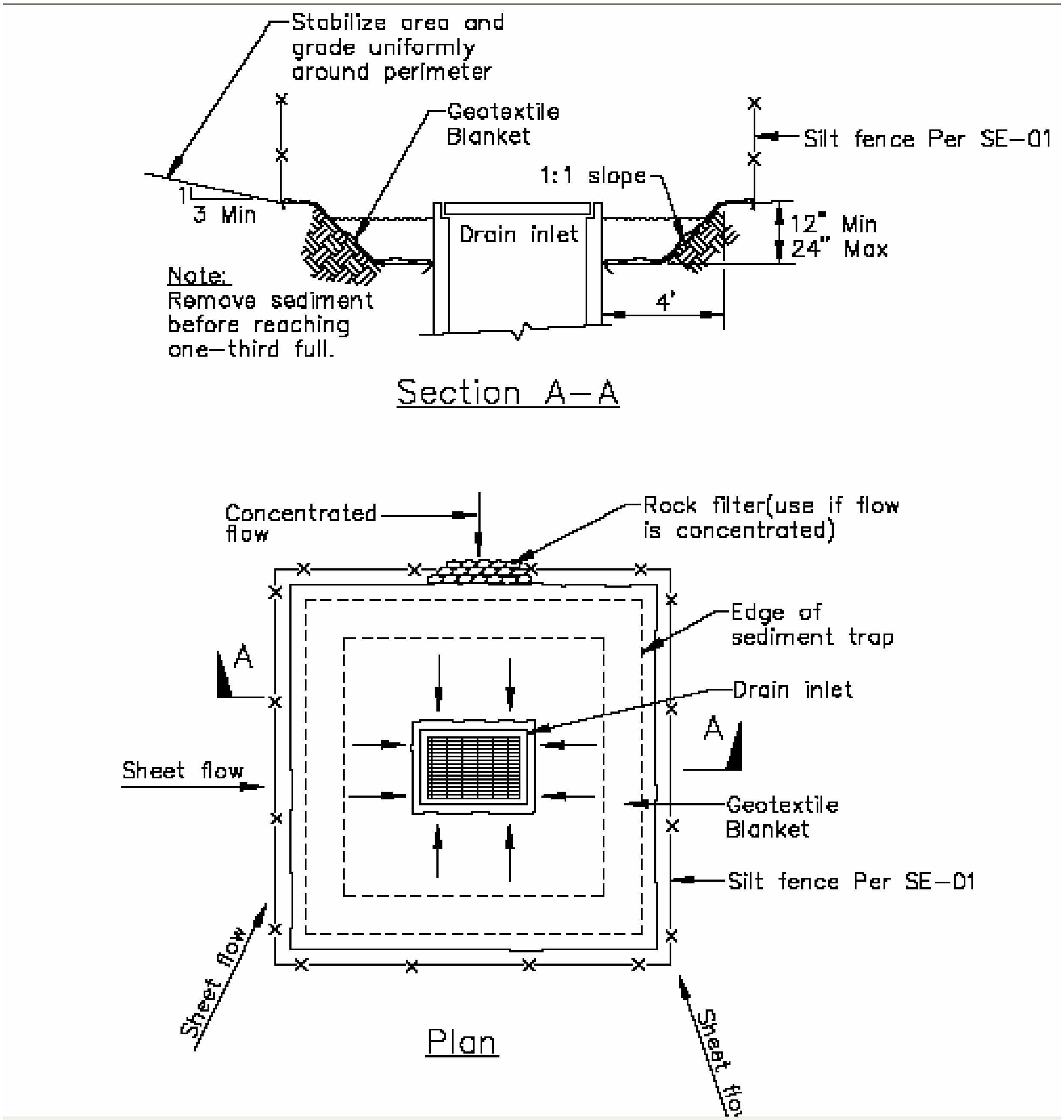

Figure 2: Excavation Around Drop Inlet

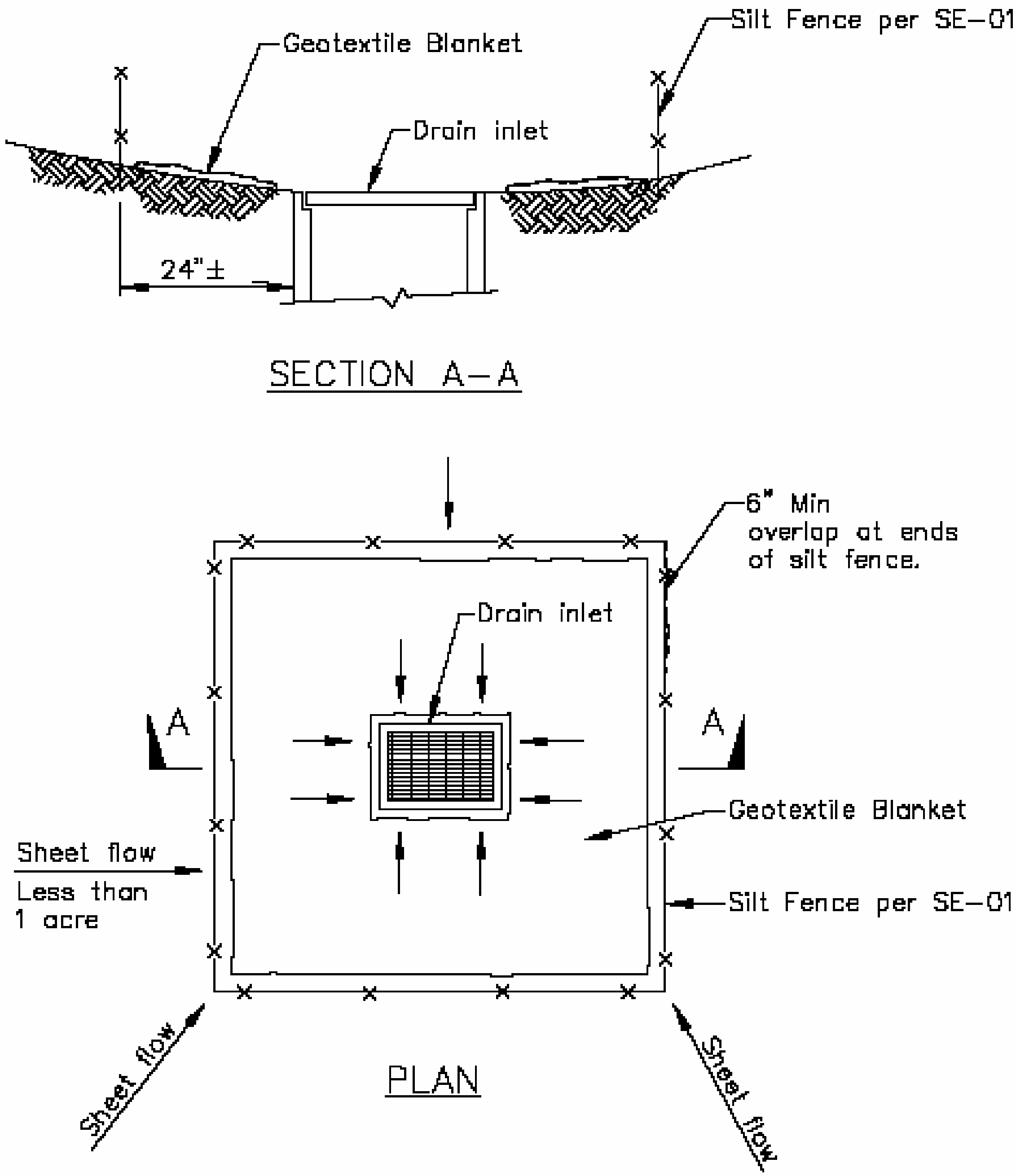

Figure 3: Filter Fabric Fence Inlet Protection

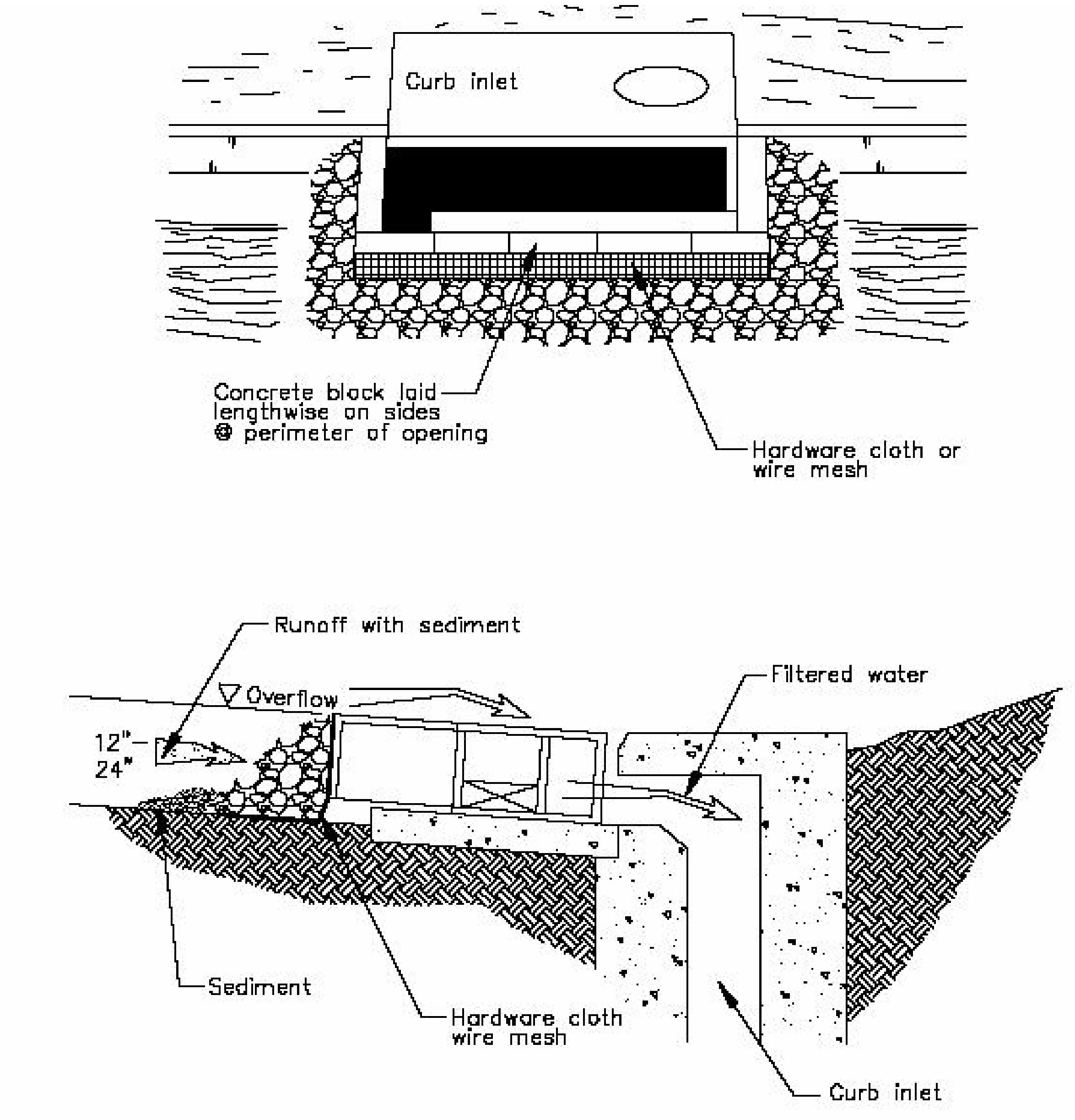

Figure 4: Block and Gravel Inlet Protection

Stream Bank Stabilization

BMP Objectives
- Erosion control
- Sediment control
- Non-Stormwater management control

Potential Alternatives
- Combination of other erosion and sediment control devices

Definition and Purpose

Stream Bank Stabilization BMPs are used to prevent stream bank erosion from high velocities and quantities of stormwater runoff. Stream channels, streambanks and associated riparian areas are dynamic and sensitive ecosystems that respond to changes in land use activity. Streambank and channel disturbance resulting from construction activities can increase the stream's sediment load, which can cause channel erosion or sedimentation and have adverse affects on the system. The use of stabilization methods can minimize the impact of construction activities on watercourses. Some typical methods include:

- Revegetation- The best way to prevent erosion and stabilize a stream bank is to keep the area vegetated.
- Armoring- Materials are applied to strengthen the stream bank. Natural materials such as logs are preferred since their shelter and decomposition help allow revegetation.
- Tree Revetments- A tree revetment, made by anchoring trees along a stream bank, is an inexpensive, effective way of stopping stream bank erosion.
- Riprap- Large angular stones placed along the stream bank or lake
- Gabion- Rock-filled wire cages that are used to create a new stream bank
- Reinforced Concrete- Concrete bulkheads and retaining walls that replace natural stream banks and create a non-erosive surface
- Log Cribbing- Retaining walls built of logs to anchor the soils against erosive forces. Usually built on the outside of stream bends

- Grid Pavers- Pre-cast or poured-in-place concrete units that are placed along stream banks to stabilize the stream bank and create open spaces where vegetation can be established

Applicability

It is appropriate to stabilize a streambed before any project that would disturb or occur within stream channels and their riparian areas. Any project that would disturb these riparian areas requires some type of stream bank stabilization.

Limitations

- This BMP does not provide the same level of water quality or aesthetic benefits of vegetative practices.
- The method chosen should be designed by qualified professional engineers, which may increase project costs.
- The material costs may be expensive.
- Additional permits may be required for the structure.
- Wildlife habitats may be negatively impacted.

Siting and Implementation Guidelines

Planning

- Stabilization should occur before any land development in the watershed area.
- Planning should take into account: scheduling; avoidance of in-stream construction; minimizing disturbance area and construction time period; using pre-disturbed areas; selecting crossing location; and selecting equipment.
- When in-stream construction is necessary, work should optimally be performed during the rainy season. This is because in the summer, any sediment-containing water that is discharged into the watercourse will cause a large change in both water clarity and water chemistry. During the rainy season, there is typically more and faster flowing water in the stream so discharges are diluted faster.
- Use other erosion and sediment control devices.
- Minimize disturbance through: selection of the narrowest crossing location; limiting the number of equipment trips across a stream during construction; and, minimizing the number and size of work areas.
- Place work areas at least 50 feet from stream channel.
- Avoid steep and unstable banks, highly erodible or saturated soils, or highly fractured rock.
- Preserving existing vegetation around a streambed provides water quality protection, soil stabilization, and riparian habitat.

Tree Revetments

- When choosing a tree, select one with many limbs and fine branches.

- Cut live trees for revetments.
- The diameter of the tree's crown should be about two-thirds the height of the eroding bank. Trees more than 20 feet tall are usually best.
- Move the first tree into place on the bank.
- Pull the tree into the stream. A tractor with a front-end loader can be used to drop trees into place.
- Pull the tree tightly against the bank and anchor at the top and the bottom.
- Pull the next tree into place and repeat the process. If smaller trees are being used, they can be placed by hand.

Riprap

- Riprap is one of the most common streambed stabilization methods.
- It is often used on steep slopes built with fill materials that are subject to harsh weather or seepage.
- Place riprap over a filter blanket.
- Use either uniform size riprap or graded applied in an even layer throughout the stream.
- Figure 1 shows a typical riprap rock filter.

Maintenance

- Regularly inspect stream bank stabilization structures, especially after a large storm event.
- Repair damage as soon as possible to prevent further damage or stream bank erosion.
- Does not usually require as much maintenance as vegetative erosion controls.

Cost

The cost for these methods varies widely according to which method is chosen.

Effectiveness

The effectiveness of these methods is varied. If closely maintained, erosion can be efficiently controlled. They are less effective in that often the installation of the devices can cause nearly as much erosion as is controlled.

Sources

- Picture Source: City of Columbia Missouri, Cosmo Park Stream Bank Stabilization Demonstration Project, http://www.gocolumbiamo.com/ParksandRec/Parks/Cosmo_Park/cosmoditch.html
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Diagrams

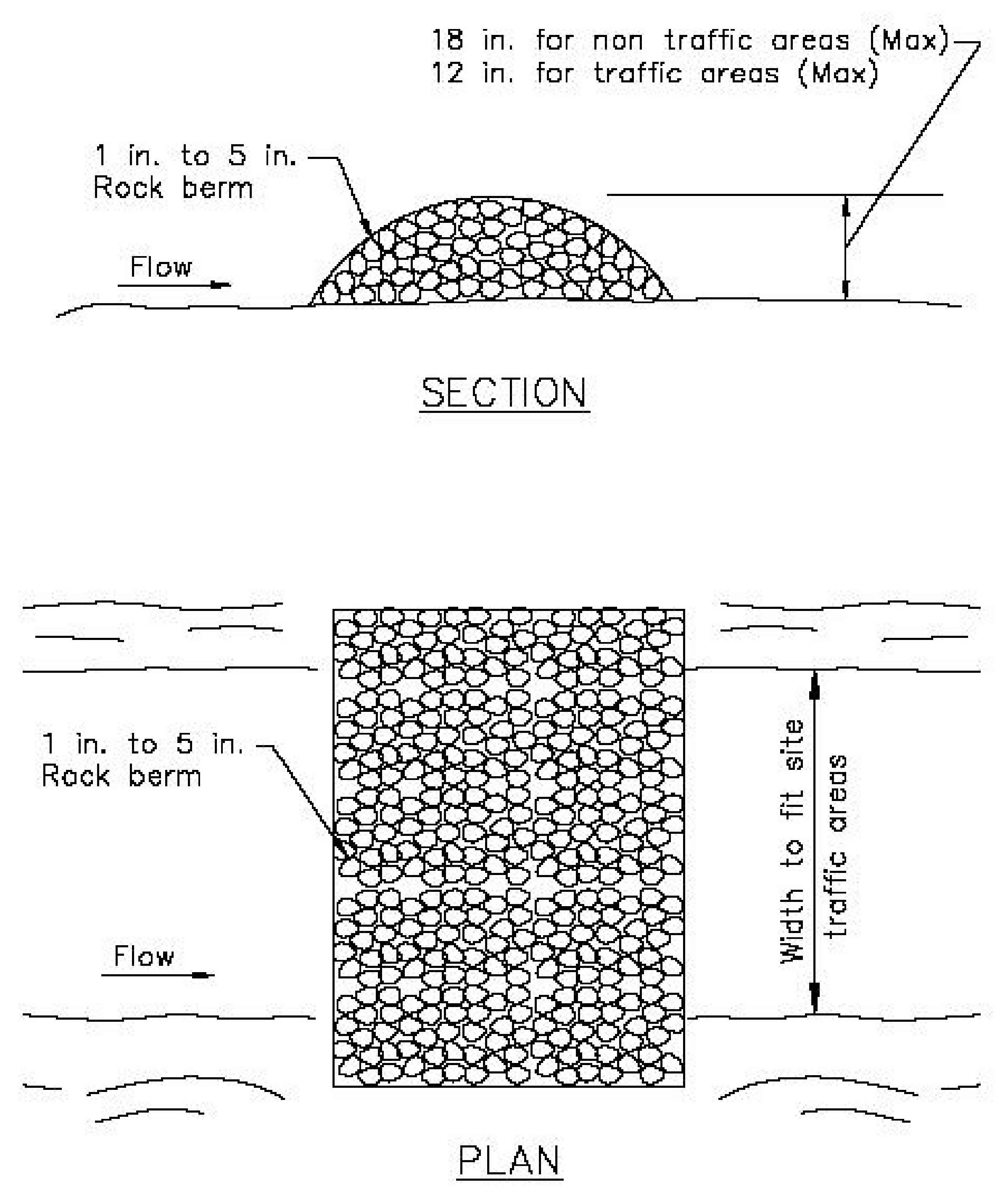

Figure 1: Riprap Rock Filter

Diversion Swale/Berm

BMP Objectives
- Erosion control
- Sediment control
- Intercept storm runoff
- Convey stormwater through construction site

Potential Alternatives
- None

Definition and Purpose

A **diversion swale or berm** is a channel of compacted soil constructed above, across, or below a slope, with a supporting earthen ridge on the lower side. It is designed to divert runoff or channel water to a desired location. When located on the upslope side of a site, these perimeter controls help to prevent surface runoff from entering a disturbed construction site. If the water never enters the site, it cannot carry off sediment. Perimeter controls located on the downslope side of a site diverts sediment-laden runoff created onsite to onsite sediment trapping devices, preventing soil loss from the disturbed area.

Applicability

Temporary perimeter control is applicable where it is desirable to divert flows away form the disturbed areas. It is often recommended that a swale or dike be built in the middle of a slope in order to reduce the length of the slope across which runoff will travel, thereby reducing the erosion potential of the flow. If the device be placed at the bottom of a sloping disturbed area, they can divert flow to a sediment trapping device. With regular maintenance, earthen diversion devices have a useful lifespan of approximately 18 months.

Limitations

- The concentrated runoff in the channel or ditch has increased erosion potential.
- Diversion swales must be directed to sediment trapping devices.

- If a diversion dike or swale crosses a vehicle roadway or entrance, its effectiveness can be reduced. Wherever possible, these perimeter controls should be designed to avoid crossing vehicle pathways.
- Swales and berms could become barriers to construction equipment.
- Earth dikes must be stabilized immediately, which adds cost and maintenance concerns.
- Regrading the site to remove the dike or swale may add additional cost.
- Earth dikes/swales are not suitable as sediment trapping devices.

Siting and Implementation Guidelines

- When siting perimeter controls, topography and the goal (prevent water from entering or exiting) are the main considerations.
- Also consider the amount of runoff to be diverted, the velocity of runoff in the diversion, and the erodibility of soils on the slope and within the diversion channel or swale.
- The quantity of and distance between the diversions should be judged by the road grade, and is detailed in Table 1.
- A diversion consists of two components: the ridge and the channel.
- Figure 1 on the Diagrams page demonstrates the following swale/dike specifications.
- The top of the ridge should be at least 2 feet wide.
- Bottom width at ground level is typically 6 feet.
- The minimum height for earthen dikes should be 18 inches, with side slopes no steeper than 2:1.
- If a channel is excavated along the dike, its shape can be parabolic, trapezoidal, or V-shaped.
- The maximum design flow velocity should range from 1.5 to 5.0 feet per second, depending on the vegetative cover and soil texture.
- If the expected life span of the diversion structure is greater than 15 days, it is strongly recommended that both the earthen dike and the accompanying ditch be seeded with vegetation immediately after construction.

Table 1: Maximum Recommended Spacing Between Diversions

Road Grade (Percent)	Distance Between Diversions (Feet)
1	400
2	250
5	125
10	80
15	60
20	50

Maintenance

- Inspect diversions regularly for damage, and repair immediately.
- Maintain the dike at original height, and repair any decrease in height due to settling or erosion immediately.
- Compact earth diversions at all times.

Cost

The cost of a diversion is broken into two parts: site preparation (excavation, placement and compacting of fill, and grading) and site development, (topsoiling and seeding for vegetative cover). Total cost of preparation has been estimated to be between $46.33 and $124.81 for a 100-foot dike with 1.5-foot-deep, 3:1 side slopes. Site development costs have been estimated between $115.52 and $375.44. The total cost is between $162 and $500. (EPA estimates.)

Effectiveness

Earthen diversions are effective as temporary devices of controlling the velocity and direction of stormwater runoff. They have no pollutant removal capability, and must be used in conjunction with a sediment trapping device at the outfall of the channel.

Sources

- Picture Source: *Neighborhood Guide to Stormwater Systems.* St. Johns River Water Management District. February 2002. http://wateratlas.co.lake.fl.us/upload/documents/bk_stormwater.pdf
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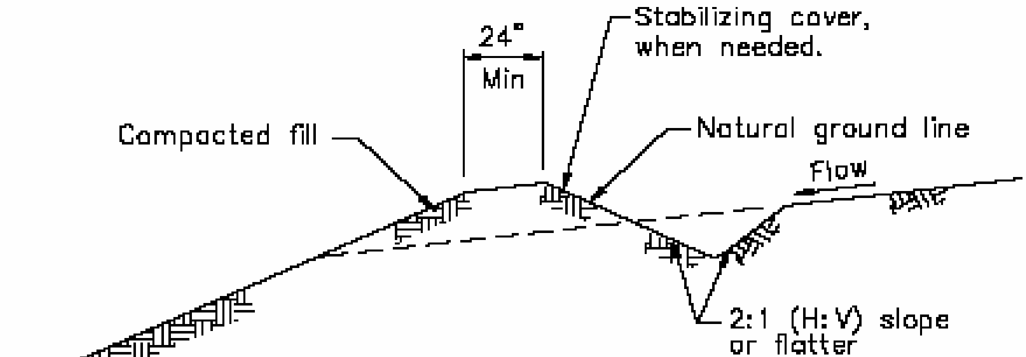
Diagrams

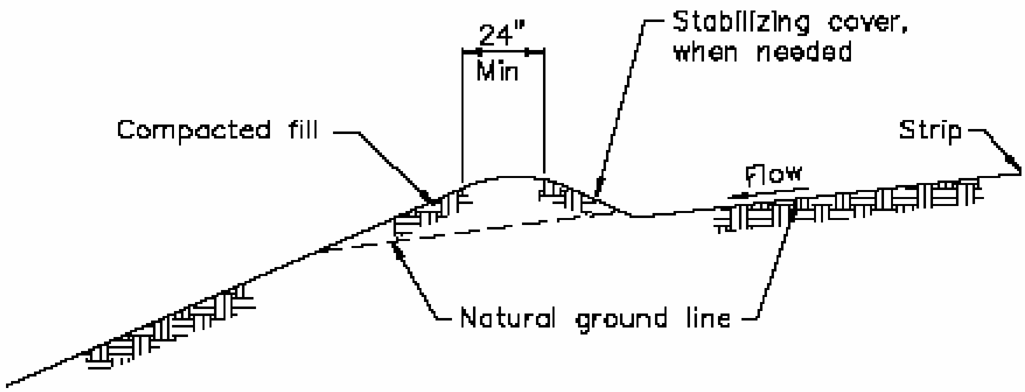


TYPICAL DRAINAGE SWALE

NOT TO SCALE

NOTES:

1. Stabilize inlet, outlets and slopes.
2. Properly compact the subgrade.



TYPICAL EARTH DIKE

NOT TO SCALE

Figure 1: Swale/Dike Construction Specifications

Sediment Basin

BMP Objectives
- Sediment control
- Retain runoff water

Potential Alternatives
- None

Definition and Purpose

A **sediment basin** is a way to capture sediment from stormwater runoff before it leaves a construction site. It allows a shallow pool to form in an excavated or natural depression where sediment from stormwater runoff can settle. Basin dewatering is achieved either through a single riser and drainage hole leading to a suitable outlet on the downstream side of the embankment or through the gravel of the rock dam. Because of this basin, water is released at a substantially slower rate than would be possible otherwise.

These sediment basins can be either a temporary (up to 3 years) structure or a permanent stormwater control measure. They can be designed to either slowly drain completely during dry periods, or so that a shallow, permanent pool of water remains between storm events.

Applicability

Sediment basins are usually used for drainage areas of 5 to 100 acres. They are often used in areas where it is anticipated that other erosion controls will not be sufficient to prevent off-site transport of sediment. There must be sufficient space and appropriate topography for the construction of a temporary impoundment. They are also often used in association with dikes, temporary channels, and pipes used to convey runoff from disturbed areas.

Limitations

- No sediment basin should be used in areas of continuously running water.

- Do not use a sediment basin where it's failure to contain stormwater will result in loss of life, or damage to homes or other buildings.
- Also, sediment basins should not be used in areas where failure will prevent the use of public roads or utilities.
- Sediment basins are attractive to children and can be very dangerous.
- Standing water may cause mosquitoes or other pests to breed.
- Sediment basins require large surface areas to allow sediment to settle.

Siting and Implementation Guidelines

General

- Sediment basins should be designed by an appropriate professional based on local hydrologic, hydraulic, topographic, and sediment conditions, meeting all local, state, and federal guidelines.
- Basins should be constructed before any grading takes place within the drainage area.
- The basin should be located to intercept runoff from the largest possible amount of disturbed area. The best locations are generally low areas.
- These devices are best used in conjunction with other erosion controls.

Installation (Three examples of basic sediment basin design are shown in Figures 1-3 on the Diagrams page.)

- Typically, the length of the basin should be more than twice the width of the basin; the length should be determined by measuring the distance between the inlet and the outlet.
- The depth should be no less than 3 feet.
- Basins should be designed to drain within 72 hours following storm events.
- Areas under embankments must be cleared and stripped of vegetation.
- Chain link fencing should be provided around each sediment basin to prevent unauthorized entry to the basin or if safety is a concern.
- The basin should be located so as to intercept the largest possible amount of runoff from the disturbed areas.
- The maximum allowable total drainage area feeding into a temporary sediment basin is 50 acres, or as approved by the City of Casper.

Sediment basins with a rock dam

- Rock dam height is typically limited to 8 feet with a minimum top width of 5 feet.
- Side slopes for rock dams should be no steeper than 2:1 on the basin side of the structure and 3:1 on the outlet side.
- The basin side of the rock dam should be covered with fine gravel from top to bottom for a minimum of 1 foot. This will slow the drainage rate from the pool tat forms and allow time for sediments to settle.
- The detention time should be at least 8 hours, or as approved by the City of Casper.

Sediment basins with earthen embankments

- Sediment basins with earthen embankments should be outfitted with a dewatering pipe and riser set just above the sediment removal cutoff level. The riser pipe should be located at the deepest point of the basin and extend no farther than 1 foot below the level of the earthen dam.
- A water-permeable cover should be placed over the primary dewatering riser pipe to prevent trash and debris from entering and clogging the spillway.
- To provide an additional path for water to enter the primary spillway, secondary dewatering holes can be drilled near the base of the riser pipe, provided the holes are protected with gravel to prevent sediment from entering the spillway piping.
- The following equation can be used to approximate the total area of dewatering holes for a particular basin:

$$A_o=(A_s \text{ x } (2h)) / (T \text{ x } C_d \text{ x } 20{,}428)$$

Where

A_o= total surface area of dewatering holes, ft^2;
A_s= surface area of the basin, ft^2;
h= head of water above the hole, ft;
C_d= coefficient of contraction for an orifice, approximately 0.6; and
T= detention time or time needed to dewater basin, hours.

Maintenance

- Basins should be inspected after each storm event, and any damage should be repaired immediately.
- Erosion from the earthen embankment or stones moved from rock dams should be replaced immediately.
- Sediment should be removed from the basin when its storage capacity has reached approximately 50 percent.
- During removal, sediment should not enter adjacent streams or drainage ways.
- Trash and debris from around dewatering devices should be removed promptly.

Cost

- Basins less than 50,000 ft^3 of storage space- installation costs range from \$0.20 to \$1.30 per cubic foot of storage (about \$1,100 per acre of drainage.) Average cost is about \$0.60 per cubic foot.
- Basins more than 50,000 ft^3 of storage space- installation costs range from \$0.10 to \$0.40 per cubic foot of storage (about \$550 per acre of drainage.) The average cost is about \$0.30 per cubic foot.

Effectiveness

The effectiveness of a sediment basin depends on the sediment particle size and the ratio of the sediment particle size and the ratio of basin surface are to inflow rate. Basins with a large surface are-to-volume ratio will be most effective. The EPA estimates an average total suspended solids (TSS) removal rate for all sediment basins from 55 percent to 100 percent, with an average effectiveness of 70 percent.

Sources

- Picture Source: Leah Blevins, 07/02/2004.
- Figures 1-3 Source: *California Stormwater Quality Association Stormwater Best Management Practice Handbook Construction*, “Sediment Basin Fact-sheet”,1993. www.cabmphandbooks.com/construction.asp
- *California Stormwater Quality Association Stormwater Best Management Practice Handbook Construction*, “Sediment Basin Fact-sheet”,1993. www.cabmphandbooks.com/construction.asp
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Diagrams

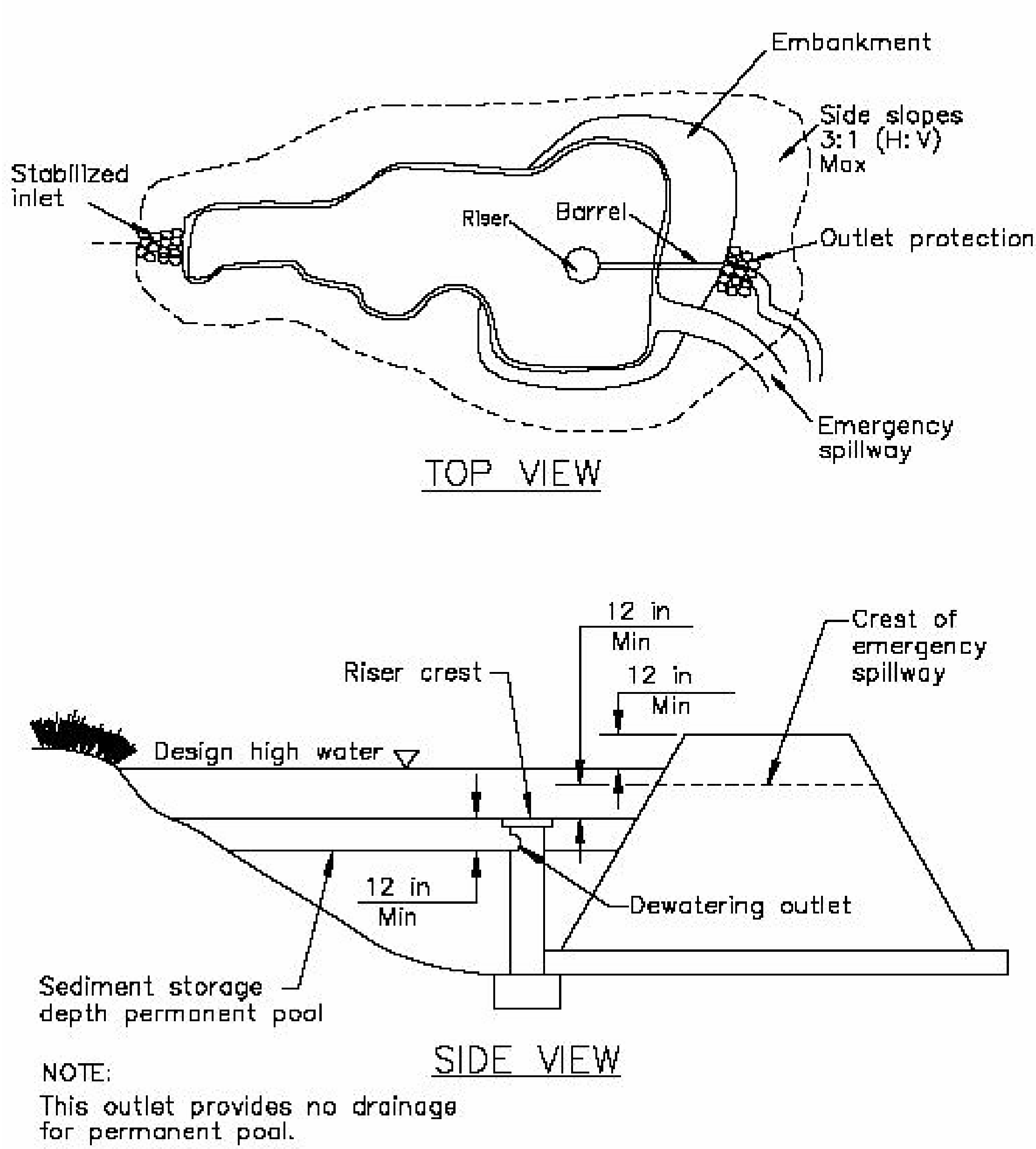

Figure 1: Typical Single Orifice Sediment Basin Design

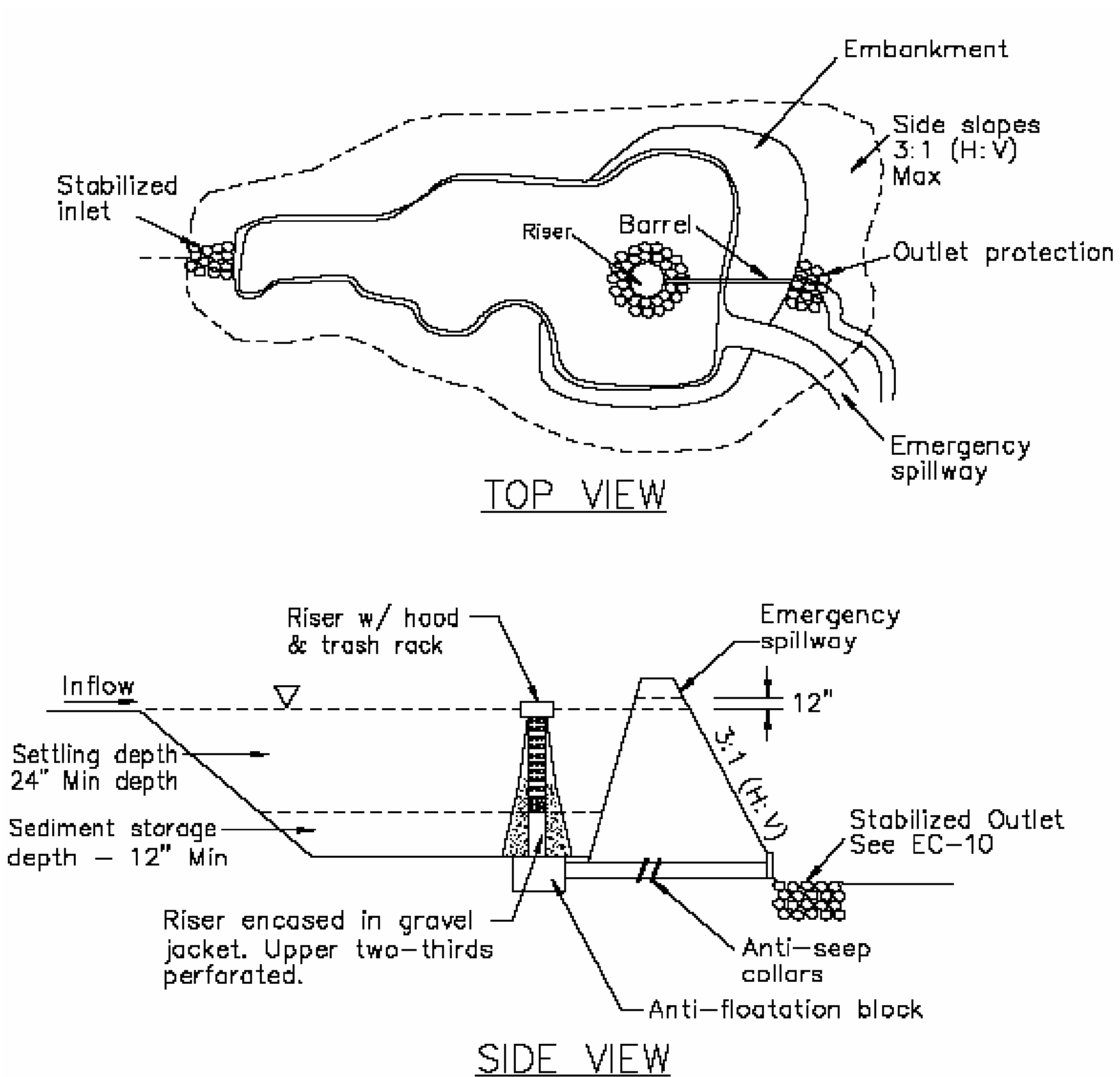

Figure 2: Typical Multiple Orifice Sediment Basin Design

Silt Fencing

BMP Objectives
- Erosion control
- Sediment control
- Reduce runoff speed
- Perimeter control
- Wind erosion control
- Reduce development of rills and gullies

Potential Alternatives
- Sandbag barriers
- Straw bale barrier

Definition and Purpose

A **silt fence** is a temporary linear sediment barrier of permeable fabric designed to intercept and slow the flow of sediment-laden sheet flow runoff. Silt fences allow sediment to settle from runoff before water leaves the construction site. They consist of a length of filter fabric stretched between anchoring posts spaced at regular intervals along the site perimeter. The fabric should be entrenched in the ground between the support posts. Silt fencing encourages sheet flow and reduces the potential for development of rills and gullies.

Applicability

Silt fences are most useful to construction sites with relatively small drainage areas. They are appropriate in areas where runoff will be occurring as low-level shallow flow, not exceeding 0.5 cfs. The drainage area for silt fences generally should not exceed 0.25 acre per 100-foot fence length. Slope length above the fence should not exceed 100 feet. Silt fences can be used around temporary stockpiles, but they should not be installed across streams, ditches, waterways, or other concentrated flow areas. They can be used to catch wind blown sand and to create an anchor for sand dune creation. Silt fences, like most erosion control methods are most effective when used in combination with other erosion controls.

Limitations

- Silt fences should not be installed along areas where rocks or other hard surfaces will prevent uniform anchoring of fence posts and entrenching of the filter fabric.
- They are not suitable for areas where large amounts of concentrated runoff are likely.
- Open areas where wind velocity is high may present a maintenance challenge.
- Silt fences should not be installed across streams, ditches, or waterways.
- Improper choice of pore size in the filter fabric or improper installation may result in failure.
- Frequent inspection and maintenance is necessary to ensure effectiveness.
- Silt fences are not intended for use as mid-slope protection on slopes greater than 4:1.
- Do not use in locations where ponded water may cause flooding.
- When construction is finished, it must be removed and disposed of.

Siting and Implementation Guidelines

- Material used for silt fences should be a pervious sheet of synthetic fabric such as polypropylene, nylon, polyester, or polyethylene yarn, chosen based on minimum synthetic fabric requirements (shown in Table 1).

Table 1: Minimum Requirements for Silt Fence Construction

Physical Property	Requirements
Filtering Efficiency	75-85% (minimum); highly dependent on local conditions
Tensile Strength at 20% (maximum) Elongation	Standard Strength: 30 lbs/linear inch (minimum) Extra Strength: 50 lbs/linear inch (minimum)
Ultraviolet Radiation	90% (minimum)
Slurry Flow Rate	0.3 gal/ft^2/min (minimum)

- If a standard strength fabric is used, it can be reinforced with wire mesh behind the filter fabric.
- The maximum life expectancy for synthetic fabric silt fences is approximately 6 months, depending on the amount of rainfall and runoff for a given area.
- Figure 1 on the Diagrams page shows the basic silt fence installation design.
- Use either wooden or metal stakes to anchor the filter fabric.
- Wooden stakes should be at least 5 feet long and have a minimum diameter of 2 inches if a hardwood such as oak is used. Softer woods such as pine should be at least 4 inches in diameter.
- When using metal posts, they should have a minimum weight of 1.00 to 1.33 lb/linear foot.
- Erect the filter fence in continuous fashion with a single roll of fabric to eliminate unwanted gaps in the fence.
- A trench should be excavated to bury the bottom of the fabric fence at least 6 inches below the ground surface.
- The height of the fence posts should be between 16 and 34 inches above the original ground surface.
- Space posts no more than 10 feet apart.

- The fence should be designed to withstand the runoff from a 10-year peak storm event.
- All silt fences should be installed along the contour, never up or down a slope.
- On slopes with grades greater than 7%, the silt fence should be located at least 5 to 7 feet beyond the base.

Maintenance

- Inspect fences regularly to ensure that they are intact and there are no gaps at the fence-ground interface or tears along the length of the fence.
- Repair torn or damaged fabric immediately.
- Accumulated sediments should be removed from the fence base when the sediment reaches one-third to one-half the height of the fence.
- Silt fences should remain in place until disturbed areas have been permanently stabilized.
- Once permanent stabilization has occurred, remove fence immediately. The results of failure to remove a silt fence are shown in Figure 2.
- When the silt fence is removed, the accumulated sediment also should be removed.
- Holes, depressions, or other ground disturbance caused by the removal of the silt fences should be backfilled and repaired.

Figure 2

Cost

Average annual costs for installation and maintenance (assuming a 6 month useful life) are $6.00 to $7.00 per lineal foot, or ($850 per drainage acre). Costs range from $3.50 to $9.10 per lineal foot.

Effectiveness

USEPA estimates the following effectiveness ranges for silt fences constructed of filter fabric that are properly installed and well maintained: average total suspended solids removal of 70 percent, sand removal of 80 to 90 percent, silt-loam removal of 50 to 80 percent, and silt-clay-loam removal of 0 to 20 percent. These removal rates are highly dependent on local conditions and installation.

Sources

- Picture Source: Arkansas Non-Point Source Management Section, Best Management Practices (BMP) Effectiveness, http://www.aswcc.arkansas.gov/NPS_Webpage/CSC/BMP%20effect.htm
- Figure 1 Source: *Urban Storm Drainage Criteria Manual, Vol. 3,* Urban Drainage and Flood Control District, Denver, Colorado, September 1999. www.udfcd.org/usdcm/vol3.htm
- Figure 2 Source: Leah Blevins, 07/02/2004.
- *California Stormwater Quality Association Stormwater Best Management Practice Handbook Construction*, "Silt Fence Fact-sheet",1993. www.cabmphandbooks.com/construction.asp
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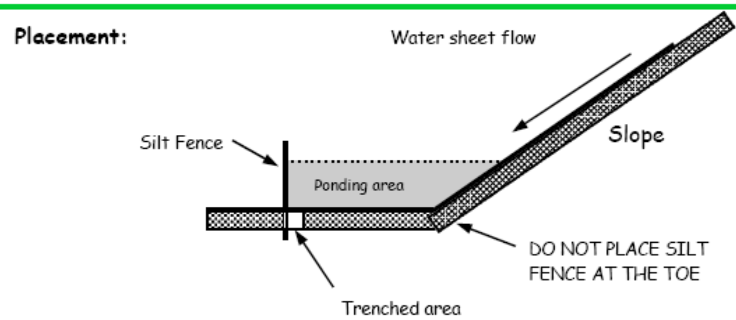
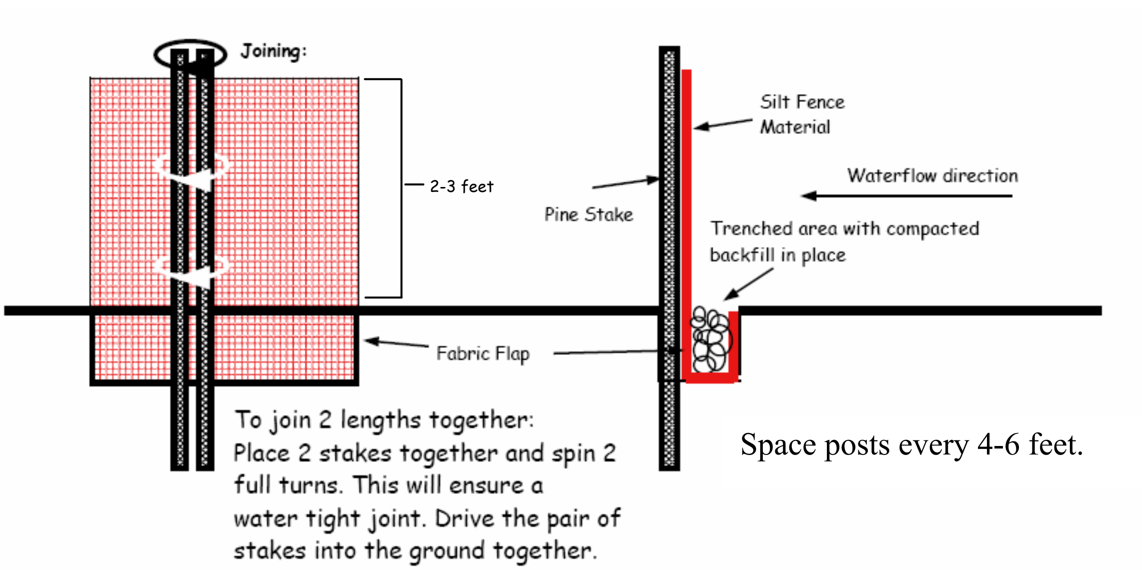
- *Tennessee Erosion and Sediment Control Handbook*, Tennessee Department of Environment and Conservation. "Silt Fence Fact-Sheet", 2002. www.state.tn.us/environment/wpc/sed_ero_controlhandbook/

Diagrams



Installation Procedures for Sediment and Silt Fence:

1. Excavate a 4” x 4” trench along the line where the silt fence will be placed.
2. Place the excavated material along the upstream (high side) of the trench.
3. Lay the silt fence out to its full width along the trench.
4. Lift each fence stake to the vertical position and drive the fence stakes in to the backside (downstream) of the trench. The stakes should be driven at least 1/3 of their length into the ground, or until the loose section of the slit fence material is completely below the surface of the ground. The minimum depth of post should be 12”. Attach the filter fence/filter fabric to posts or the sewn pockets over post and extend it into the trench.
5. Lay the silt fence fabric flap (skirt) into the excavated area so that all of the backfill material will be placed on the skirt in the trench.
6. Backfill and tamp (compact) the excavated material into the trench. The silt fence fabric flap should be securely toed into the ground, so that you cannot pull it out.
7. It is essential that you maintain your installation.



Erosion Control Fencing

BMP Objectives
- Erosion control
- Sediment control
- Reduce wind velocity
- Prevent off-site road damage

Potential Alternatives
- Dust control measures

Definition and Purpose

Erosion control fences are barriers of small, evenly spaced wooden slats or fabric installed at right angles to the prevailing wind erected to reduce the wind velocity and trap blowing sand. They are intended to prevent off-site transportation of fine dust moved by wind. The spaces between fence slats allow wind and sediment to pass through but reduce the wind velocity, which causes sediment deposition along the fence.

Applicability

These fences are applicable in areas with high wind speeds that transport a great deal of fine soils off-site. They are especially advantageous for construction sites with large areas of cleared land or in arid regions where blowing sand and dust are especially problematic.

Limitations

- A wind fence does not control sediment carried in stormwater runoff.
- These fences should be installed with other erosion control methods that prevent stormwater runoff.

Siting and Implementation Guidelines

- Erect fences as close to perpendicular to the prevailing wind as possible.

- Wind fences have been shown to be effective up to 22.5 degrees from perpendicular, but the closer to perpendicular they are, the more sand/sediment is trapped.
- It is most effective to erect multiple fences. Linear rows of fence 2 to 4 feet high and spaced 20 to 40 feet apart can be installed. The spacing must not exceed a ratio of 10:1 (width to height.)

Maintenance

- Periodically inspect fences to ensure that there are no breaks or gaps.
- Make repairs immediately.
- Clean sand and sediment from the fence area periodically to prevent stormwater from transporting them off the site.

Cost

Wind and sand fences are relatively inexpensive to purchase, install, and maintain because they are small, easy to transport, lightweight, and constructed of low-cost materials.

Effectiveness

These fences can be effective as a sand trapping device, but are not adequate as a primary dust-control or sediment trapping measure. Their effectiveness is assured only in conjunction with other sediment control devices.

Sources

- Picture source: Leah Blevins, 07/02/2004.
- National Pollutant Discharge Elimination System (NPDES) website, "Construction Site Storm Water Runoff Control: Wind Fences and Sand Fences." http://cfpub.epa.gov/npdes/stormwater/menuofbmps/site_26.cfm

Stabilized Construction Entrances/Exits

BMP Objectives

- Erosion control
- Sediment control
- Tracking control

Potential Alternatives

- None

Definition and Purpose

Stabilizing a construction entrance consists of a stone-stabilized pad located at any point where traffic will be leaving a construction site to a public roadway. Installing a pad of gravel over filter cloth where construction traffic leaves a site causes mud and sediment to be removed from the vehicle's wheels when it drives over the gravel pad, and offsite transport of soil is reduced. The filter fabric separates the gravel from the soil below, preventing the gravel from being ground into the soil.

In addition to the gravel, it is also wise to establish a vehicle washing station at the site entrance. Runoff from this washing station should be diverted into a sediment trap and disposed of properly.

Applicability

Construction entrance/exit stabilization is applicable at any location where construction traffic leaves or enters an existing paved road. This is a very useful public relations tool, as the entrance/exit is the most publicly visible aspect of many construction sites. Entrance stabilization can improve the appearance to passersby and improves public perception.

This practice is also useful on sites adjacent to water bodies, and where surrounding soils are poor.

Limitations

- Despite the stabilization mechanisms, some soil may still be deposited from construction vehicles onto paved surfaces, necessitating sweeping of the paved area.
- If using a wash station, a reliable water source must be made available.
- Entrances/exits require periodic top dressing with additional stones.
- Entrances/exits should be constructed on level ground only.

Siting and Implementation Guidelines

- Figure 1 on the Diagrams page shows a typical construction exit.
- Entrances should be stabilized before the construction begins.
- Make the entrances long and wide enough that the largest vehicle to enter the site will fit in the entrance with room to spare.
- If it is expected to be a high-traffic entrance it should be wide enough for the passage of two vehicles at the same time with room to spare.
- If a site entrance leads to a paved road, the end of the entrance should be "flared" (made wider as in the shape of a funnel) so that long vehicles do not leave the stabilized area when turning onto or off of the paved roadway.
- Stones and gravel used in stabilization should be large enough that they are not carried away on construction traffic. They should also not be sharp-edged stones because of the risk of punctured vehicle tires.
- Install the gravel at a depth of at least 6 inches the entire length and width of the entrance.
- Limit the points of entrance/exit to the construction site.
- Limit the speed of entering vehicles to control dust.
- Properly grade each construction entrance to prevent runoff from leaving the site.

Maintenance

- Inspect and maintain entrances until construction site has been fully stabilized.
- Periodically add stone and gravel to the entrance to maintain effectiveness.
- Sweep errant soil immediately for proper disposal.
- Periodically remove the sediment from traps.
- Keep all temporary roadway ditches clear.
- Remove gravel and filter fabric at the end of construction.

Cost

Average annual cost for installation and maintenance may vary from $1,200 to $4,800 each, averaging $2,400 per entrance. Costs will increase with the addition of a washing rack and sediment trap. With the wash rack, costs range from $1,200 to $6,000, averaging $3,600 per entrance.

Effectiveness

This method is effective only if it is carried out on all entrances. Otherwise the sediment saved at one entrance exits another. Effectiveness is optimized when a wash station is installed and used.

Sources

- Picture source: U.S. Environmental Protection Agency, National Pollutant Discharge Elimination System (NPDES), "Construction Site Storm Water Runoff Control: Constructin Entrances", http://cfpub.epa.gov/npdes/stormwater/menuofbmps/site_7.cfm
- Figures 1 Source: *Tennessee Erosion and Sediment Control Handbook*, Tennessee Department of Environment and Conservation. "Construction Exit Fact-Sheet", 2002. www.state.tn.us/environment/wpc/sed_ero_controlhandbook/
- *California Stormwater Quality Association Stormwater Best Management Practice Handbook Construction*, "Stabilized Construction Entrance/Exit Fact-sheet",1993. www.cabmphandbooks.com/construction.asp
- National Pollutant Discharge Elimination System (NPDES) website, "Construction Site Storm Water Runoff Control: Construction Entrances." http://cfpub.epa.gov/npdes/stormwater/menuofbmps/site_7.cfm
- *Tennessee Erosion and Sediment Control Handbook*, Tennessee Department of Environment and Conservation. "Construction Exit Fact-Sheet", 2002. www.state.tn.us/environment/wpc/sed_ero_controlhandbook/

Diagrams

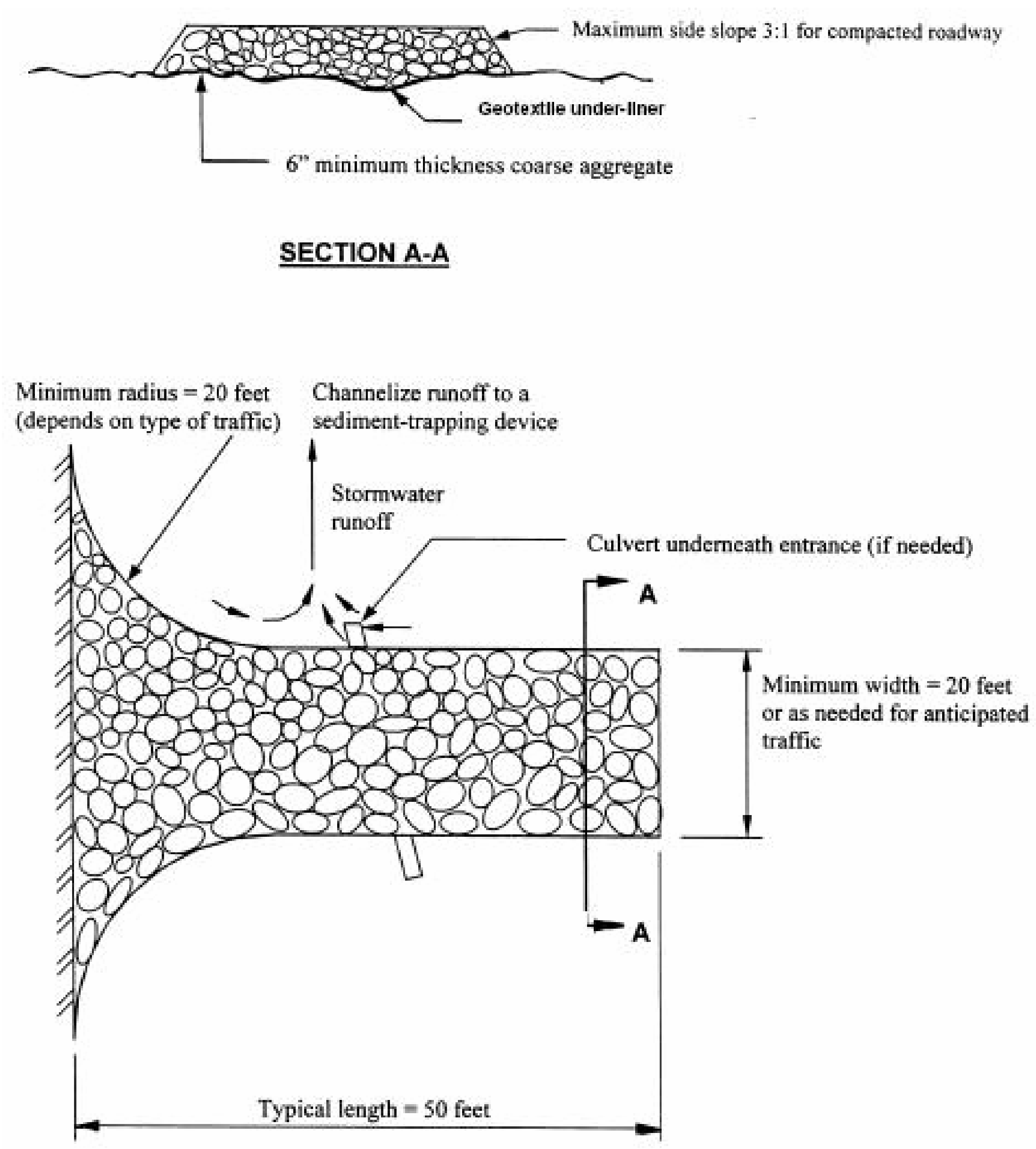


Figure 1: Stabilized Construction Exit

Dust Control

BMP Objectives
- Sediment control
- Wind erosion control

Potential Alternatives
- None

Definition and Purpose

Dust control or wind erosion control consists of applying dust suppressants as necessary to prevent soil erosion. Construction sites are good candidates for dust control measures because land disturbance from clearing and excavation generates a large amount of soil disturbance and open space for wind to pick up dust particles. The two main threats from dust are: 1) sediment and water pollution from dust carried off-site, and 2) respiratory health problems and inhospitable working environment due to blowing dust problems. In accordance with City of Casper Ordinance, watering of construction areas shall not constitute an approved BMP for erosion and sediment control. Chemical stabilizers shall be used for sediment and erosion control.

Applicability

These controls should be considered for any exposed soils that may be eroded by the wind. Earthmoving activities are the major source of dust, but any traffic can contribute. They are also useful for soil storage piles and areas with unstabilized areas.

Limitations

- Some types must be reapplied or replenished regularly. If evaporation is high, water reapplication may need to be nearly constant.
- The spray of water may cause increased offsite tracking of mud.
- These methods are not as effective as other controls, such as seeding and mulching.

- Effectiveness depends on soil, temperature, humidity, wind velocity, and wind direction.
- Over watering may cause erosion.

Siting and Implementation Guidelines

- The amount of soil exposed will dictate the quantity of dust generation and transport.
- If land must be disturbed, use additional erosion and stabilization methods
- Table one shows a list of dust control options, and where they can be effectively utilized. See other Fact Sheets for more information.

Table 1: Appropriate Site Conditions for Dust Control Practices

Site Conditions	Practices								
	Permanent Vegetation	Mulch	Watering	Chemical Suppression	Gravel or Asphalt	Silt Fence	Construction Entrances	Haul Truck Covers	Minimize Disturbed Area
Not Subject to Traffic	X	X	X	X	X				X
Subject to Traffic			X	X	X		X		X
Stock Pile Stabilization			X	X		X			X
Demolition			X				X	X	
Clearing/ Excavating			X	X		X			X
Truck Traffic on Unpaved Roads			X	X	X		X	X	
Mud/Dirt Carry Out					X		X		

Maintenance

- For maintenance of various methods, see other Fact Sheets.
- Monitor BMPs for effectiveness.

Cost

A manufacturer of a chemical stabilizer estimated the cost to be $1,089 per acre for application to road surfaces, but the costs could vary widely. Also, aggregate costs could be much higher because of the necessity of frequent application.

Effectiveness

The methods have varying levels of effectiveness, and most can be found on their individual fact sheets. Chemical soil treatments effectiveness ranges from 70 to 90 percent. Water spraying is also effective in the short time until it dries.

Sources

- Picture Source: Soltac, Applications Methods website, www.soiltac.com/Application_Methods.html
- *California Stormwater Quality Association Stormwater Best Management Practice Handbook Construction*, "Wind Erosion Control Fact-sheet",1993. www.cabmphandbooks.com/construction.asp
- *Erosion and Sediment Control Best Management Practices: Field Manual,* Montana Department of Transportation, "Wind Erosion Control Fact Sheet", 2003. www.mdt.state.mt.us/research/projects/env/erosion.shtml
- National Pollutant Discharge Elimination System (NPDES) website, "Construction Site Storm Water Runoff Control: Dust Control." http://cfpub.epa.gov/npdes/stormwater/menuofbmps/site_11.cfm
- *Storm Water Management For Industrial Activities, Developing Pollution Prevention Plans and Best Management Practices, Chapter Four.* U.S. Environmental Protection Agency. "Dust Control (Land Disturbance and Demolition Areas Fact-sheet", 1992. www.epa.gov/npdes/pubs/chap04_inguide.pdf
- *Casper Wyoming Municipal Code*. Chapter 12.20.065, "Erosion and Sediment Control- Plan Requirements." http://municipalcodes.lexisnexis.com/codes/casper/

Street Sweeping and Vacuuming

BMP Objectives
- Sediment control
- Tracking control
- Soil stabilization

Potential Alternatives
- None

Definition and Purpose

Street sweeping is a practice used to remove soil and other sediments from streets and roadways in order to prevent them from entering storm drains and receiving. Self-propelled and walk behind equipment are used in the sweeping and vacuuming process.

Applicability

It is appropriate to sweep the streets anywhere where sediment is tracked onto public or private paved streets, typically at the area of construction entrance/exit.

Limitations

- Sweeping is not very effective when the sediment is wet, or when it is caked on.
- Do not used kick brooms or sweeper attachments.
- Visible sediment must be swept on a daily basis.

Siting and Implementation Guidelines

- Control the number of entrances/exits so that sweeping will be necessary in fewer places.
- Sweep sediment on a daily basis.
- Do not use kick brooms or sweeper attachments, as dirt will only be spread, not removed.

- If there is no trash or debris, consider incorporating the removed sediment back into the project.

Maintenance

- Inspect access points at least daily to sweep up sediment.
- Do not sweep up any unknown substances.
- Adjust brooms frequently, maximizing the sweeping operations.

Cost

Rental rates vary depending on the size of the sweeper. Rates range from $58/hour to $88/hour, plus operator costs.

Effectiveness

If used at an appropriately frequent rate, sweepers can remove any sediment on paved ground.

Sources

- Picture Source: City of Berkeley, California Public Works Department, "Residential Street Sweeping Program" http://www.ci.berkeley.ca.us/pw/swm/stsweep.html
- *California Stormwater Quality Association Stormwater Best Management Practice Handbook Construction*, "Street Sweeping and Vacuuming Fact-sheet",1993. www.cabmphandbooks.com/construction.asp
- *Erosion and Sediment Control Best Management Practices: Field Manual,* Montana Department of Transportation, "Street Sweeping and Vacuuming Fact Sheet", 2003. www.mdt.state.mt.us/research/projects/env/erosion.shtml