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SOIL EROSION AND SEDIMENT CONTROL TECHNIQUES FOR DISTURBED LANDS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Telena Dianna Moore

August 1992

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DEDICATION

I would like to dedicate my thesis to my grandmother (Nellie Forsythe), my mother (Hallie), my brothers (Jody and Victor Fred), my sisters (Amanda and Lori), and my father (Bud). Although my family could not help me financially, they did provide ample amounts of love and support that helped to give me the strength to succeed with my education. My grandmother and father have passed away and even though my father would have rather seen me become a nurse, I am sure they are all very proud of me.

ACKNOWLEDGEMENT

I would like to thank Drs. Tschantz, Smoot, Soliman, and Deatherage, and the entire Civil/Environmental engineering staff for their patience and help while attending the University of Tennessee, Knoxville. Special thanks goes to Drs. Tschantz and Smoot for helping to provide me with the opportunity, support, and means to obtain a much desired Master of Science degree in Environmental Engineering. Thank you all.

ABSTRACT

Research into control techniques for sediment-related nonpoint source pollution indicates that many current field practices are not effective. Current technology appears sufficient to control many soil erosion and sediment problems, however, improper selection, placement, and maintenance appear to be common problems. This thesis provides guidance for application, design, and maintenance, and to help give insight into common troubles associated with selected soil erosion and sediment control techniques. The references used in preparing this thesis were obtained by literature review, written and verbal communication with individuals involved in the related practice (such as manufacturers and field inspectors), and through field observation.

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SECTION I

INTRODUCTION

BACKGROUND

Soil erosion is a naturally occurring process which is essential in establishment of the earth's surface as we know it. The average natural geologic rate of soil erosion is approximately 0.2 tons per acre per year (Leet and Judson, 1974). The earth's biosphere has evolved to depend on the erosion process. Wind, water, ice and gravity are components of nature that can cause soil erosion. However, problems arise when excessive sediment invades an ecosystem and causes an imbalance of sediment load to a system to occur. Land-disturbing activities such as construction and mining operations can alter the protective ground cover and expose the surface, making it vulnerable to erosion. For example, unprotected construction sites can experience annual soil loss rates in excess of 150 tons per acre per year while strip mines may experience more than 1,000 tons per acre per year -- more than 750 and 5,000 times the average natural rate, respectively. Some environmental impacts caused by excessive sediment induced into a natural system are as follows (modified from Eagan, 1990; University of Wisconsin-Madison, 1990; and Virginia Soil and Water Conservation Commission, 1980):

- Suspended sediment can cause light limitation which can inhibit photosynthesis and reduce the vital plant life necessary for the basic aquatic food chain. Additionally, this can effect game fish that rely on sight to feed, making them less competitive.

- Suspended sediment can cause abrasion to fish gill linings thus promoting disease and parasites.

- Settlement of suspended sediment can smother or cover food sources and/or permanently alter living habitats of aquatic insects, hatching areas, and small organisms living on the bottom to the point of sterilization.

- Suspended sediment can carry with it pollutants such as nutrients (especially phosphorous and nitrogen), pesticides, debris, oil, PCB's, oxygen demanding substances, bacteria, and others.

- Sedimentation can cause loss of water surface area (such as lakes and rivers) and loss of volumetric flood storage thus causing more frequent flooding.

- Increases in domestic or industrial water treatment cost can be caused by excessive sediment.

- Sediment can fill drainage channels, clog culverts and storm drains, cause municipal and industrial water supply reservoirs to lose storage capacity, and block navigable channels.

Induced sediment is very costly in terms of the expenses necessary for correcting the damage. These problems could be greatly reduced if Best Management Practices (BMP's) in soil erosion and sediment control practices are employed at the initial sediment producing source.

SOIL EROSION AND SEDIMENTATION PROCESS

Soil erosion by water can be caused by rainfall impact that pounds the surface and causes aggregates to break up (referred to as raindrop erosion), and then by the shearing force of flowing water as it travels across the downgradient surface, dislodging soil particles in its path. Suspended sediment occurs when the flowing water carries with it the loosened particles. This process is increased when the protective land cover is altered, making the surface more vulnerable to the pounding action of the rainfall and to the scouring action of flowing water. The types of erosion caused by this process are typically referred to as raindrop, sheet, rill, gully, and channel erosion (see Figure 1). (Smoot, et al., 1992)

Sheet erosion occurs when the rainfall begins to collect and run off in a uniform sheet causing the outermost surface to erode. Sheet erosion is the most difficult to visually detect due to the uniformity of thin layers being eroded. As these sheets travel downslope, they tend to shear and dislodge looser, less dense portions of the surface to create small channels that can range to several inches in depth. The creation of these small channels are usually referred to as rill erosion. Rills can combine causing increases in concentrated flow and velocity. Gully erosion then develops as the channels continue to carve even deeper into the surface. Gullies are similar to rills except they may be several feet or more in depth and usually require employment of heavy equipment along with special techniques to correct because once formed, they are more apt to redevelop. (Smoot, et al., 1992)

Natural streams or stormwater conveyance channels erode and deposit sediment in order to stabilize themselves. Equilibrium for most natural streams appears to conform to approximately a 2-year frequency maximum storm event (Stem, 1975). Construction and urbanization typically increase peak flows thus upsetting the long-term equilibrium balance between natural flow and stream morphology prior to construction. Increasing a stream's sediment load can reduce the volume of the channel which also causes a state of disequilibrium to develop. The drainageway will then seek a new equilibrium stage. Stream morphology is slow to respond or conform to human-induced sediment loads and as a result, excessive erosion and sedimentation may occur along the channel (note Figure 1).

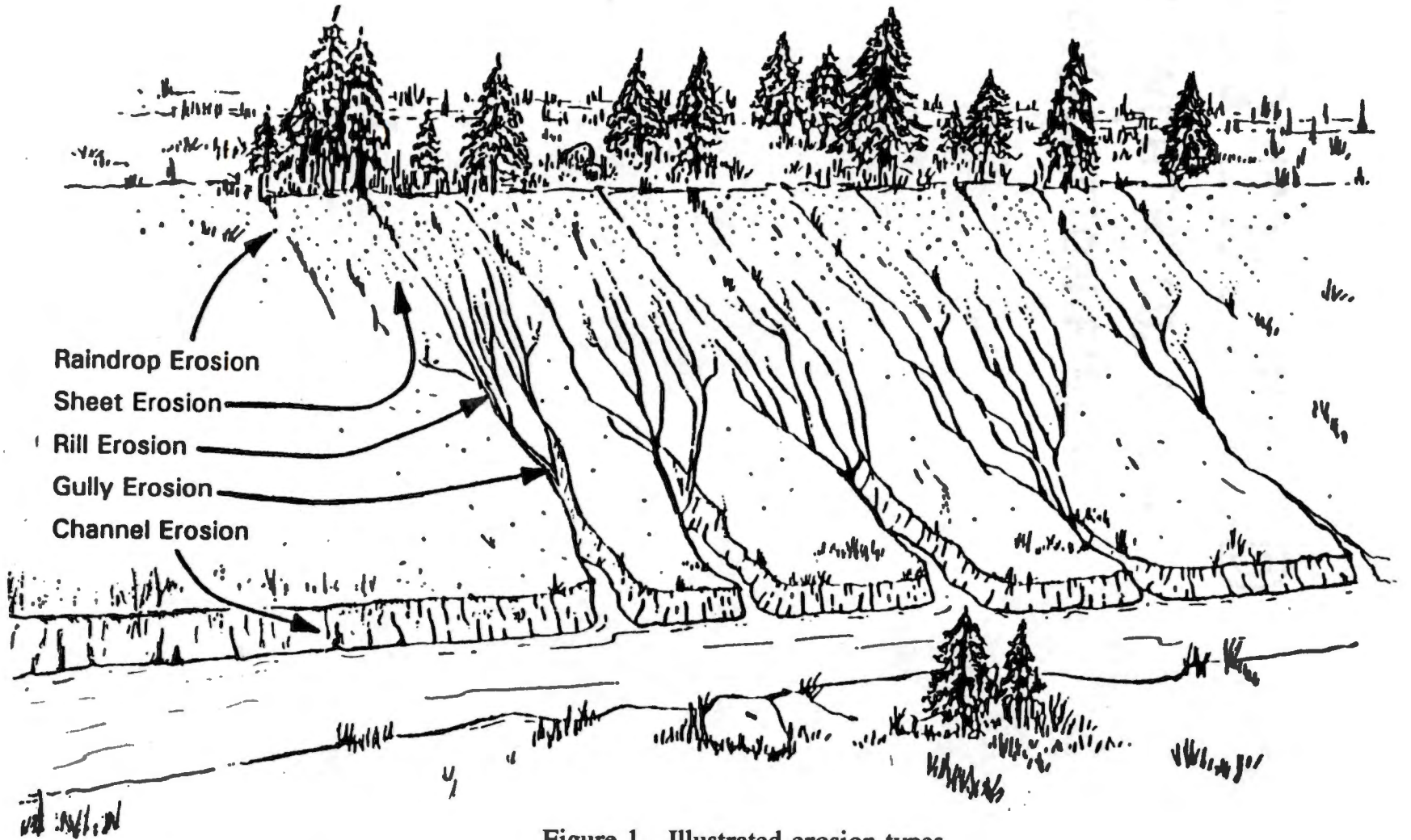


Figure 1. Illustrated erosion types.

Source: Colorado Department of Highways, Erosion Control Manual. Colorado Department of Highways in cooperation with the U.S. Department of Transportation, Federal Highway Administration (1978).

Transported suspended sediment will settle as velocities decrease and gravitational forces dominate. This process is often referred to as sedimentation. Coarser, denser particles (such as sands) will precede the finer, less dense particles (such as fine clays and silts) when settling. This is due to the finer, less dense particles requiring slower velocities and longer time to gravimetrically settle out than the coarser, heavier particles. The process of erosion, transport, and deposition is referred to as the sedimentation cycle. (Goldman, et al., 1986)

BASIC PRINCIPLES OF SOIL EROSION AND SEDIMENT CONTROL

Through research and experience (trial and error) many effective methods for significantly reducing the rate of soil erosion and sediment transport have been developed. The most effective steps in retarding the erosion process and controlling sediment transport are as follows (modified from University of Wisconsin-Madison, 1990; and Virginia Soil and Water Conservation Commission, 1980):

(1) Minimize (or eliminate) on-site erosion as a first-line strategy through various management practices such as:

- Fit the site being developed to the terrain;
- Physically retard the runoff velocities and flows;
- Minimize the size of denuded areas and duration of exposure to the elements;
- Protect denuded areas from erosive forces by using vegetation, mulch, and/or matting;
- Retain existing vegetation when feasible; and
- Divert runoff away from denuded areas.

(2) Control or minimize sediment transport off site as a second line of defense by:

- Trapping the sediment from sediment-laden runoff on-site; and
- Frequently inspect and maintain control measures.

The last principle involving the inspection and maintenance of erosion/sediment management facilities is an essential step in helping to retain sediment on-site. One common problem in erosion and sediment control is the neglect of inplace controls. When maintenance is neglected, failure can occur to the extent that resulting adverse

environmental effects are as severe as if no control practices were applied. Failure could be catastrophic if a control such as a large sediment dam was to fail. (Kouwen, 1990)

The larger the exposed area, the longer the time the area is unprotected by vegetation, and the steeper the slopes--the greater the potential soil erosion problem. An effective control strategy is to stage a site at smaller work increments and using the various methods of soil erosion and sediment control in combination with one-another. Staging the denudation of a site in smaller increments, providing immediate protective cover to those portions completed or dormant, and ensuring that the proper selection, installation, and maintenance is given to the control practices in place will help reduce sediment related non-point source pollution and overall long term environmental, social, and maintenance cost.

APPLICATION OVERVIEW

Often, inspectors and contractors are not trained in the proper application and maintenance of soil erosion/sediment control devices. The material in this thesis can be very useful to individuals involved with the inspection and maintenance of such controls. Many engineering graduates are also not specifically trained in erosion/sediment control techniques and may be faced with design of such upon entering the engineering work force. Soil erosion and sediment control plans prepared prior to land-alternating activities is becoming a common requirement in the state of Tennessee. Many designers are now faced with the development of erosion control plans.

This thesis was organized and developed to provide an "easy-to-follow" guide into the proper selection, design, installation, and maintenance of several technologies that can help reduce sediment-related nonpoint source pollution. A summary of each section follows.

Section II, "Vegetative and Structural Protective Cover", contains the following procedures: temporary seeding; permanent seeding; trees, shrubs, vines, and ground cover; mulching; sodding; erosion control matting; and topsoil. The vegetative cover subsections accommodate species suited to the various conditions associated with Tennessee's terrain and climate. The objective of this section is to present various methods that can be used in providing immediate protective cover to denuded areas. Providing immediate cover to denuded areas is the most effective means of preventing the displacement of the soil and, thus, controlling the erosion process. It is more efficient and cost effective to prevent erosion from occurring using these procedures than it is to try and separate the resulting suspended sediment from the runoff.

When it is not practical to provide immediate cover to a disturbed area, then it is desirable to contain the suspended sediment on-site prior to entry of runoff into receiving waters. Sections III and V deal primarily with methods used for treatment of suspended sediment.

Section III, "Basic Sediment Barriers", contains the following procedures: straw bale barrier; silt fence barrier; and brush barrier. These methods help to trap the suspended sediment on-site and to slow water

velocities which help minimize further erosion. These devices function by ponding the waters, which slow velocities and allow for some settlement of the suspended sediments. Although these procedures are desirable methods in treatment of suspended sediment, they are only, at best, 60 to 70% effective, becoming less effective with fine silts and clays which require long settling times (Kouwen,1990). These methods used in conjunction with sediment detention ponds and basins will increase the overall suspended sediment trapping efficiencies.

Section IV, "Water Conveyance", contains the following procedures: diversions; temporary slope drain; check dam; outlet protection; and inlet protection. These techniques help to prevent scour and minimize erosion by reducing the velocities of concentrated flows. The inlet protection subsection also reviews methods to prevent suspended sediment from entering and clogging storm drainage systems.

Section V, "Sediment Detention Ponds and Basins", covers temporary sediment traps and sediment basins. These procedures capture the sediment-laden runoff in large holding areas which slow the velocities and allow time for settlement of the suspended sediment. Ideal pond design is often impossible, therefore, guidelines for creating an efficient system from what is available is also discussed.

Section VI, "Stream and Streambank Protection", contains the following procedures: temporary stream crossing; temporary stream diversion; and riprap. These methods are used to minimize erosion when it is necessary to cross, or work within, streams.

Section VII, "Temporary Construction Road Stabilization" discusses procedures useful in preventing on-site sediment from being transported off-site by vehicular traffic.

Some primary references used in the creation of each subsection are included at the end of each subsection. These references should prove useful when additional information is desired about certain procedures.

A Glossary of common soil erosion and sediment control terms is included in the Appendix.

SECTION II

VEGETATIVE AND STRUCTURAL PROTECTIVE COVER

TEMPORARY SEEDING

DESCRIPTION

Temporary stabilization of soil with rapidly growing annual plants is used to prevent erosion on disturbed areas before final grading or in a season not suitable for permanent seeding. Areas of bare earth are often left exposed to rain and runoff for weeks. Damage from erosion or stormwater runoff costs time and money for regrading or other repairs. Vegetative cover is the most efficient and economical means of managing sheet and rill erosion.

WHERE TEMPORARY SEEDING IS USED

Temporary seeding should be applied where final grading of exposed surfaces are to be completed within 15 days to a year. Such areas include denuded areas, soil stockpiles, dikes, dams, sides of sediment basins, and temporary diversions.

When the desired permanent seed cannot be applied due to the season, a temporary seed appropriate for the season may be applied. Such applications may prevent costly maintenance operations of other erosion control systems.

BASIC DESIGN AND CONSTRUCTION GUIDELINES

Site Preparation

To help prevent the seed from washing away during establishment, the area should be protected with such methods as surface roughening and diversions (see "Diversions" subsection of Section IV for guidance). Surface roughening can be performed easily with a tracked vehicle running perpendicular up and down a slope.

Soil samples should be taken from the site and analyzed for fertilizer and lime requirements. Lime and fertilize should be applied as required based on soil sample results, else fertilizer should be applied at a rate of 5 pounds per 1,000 square feet with commercial grade 10-10-10

(nitrogen-phosphorus-potassium) fertilizer or equivalent. Extremely acidic soil (pH 5.5 or lower) should be limed at approximately 2 tons per acre.

Seed Selection

Select appropriate temporary species adaptable to the time of year. Avoid seeding in December or January. If necessary to seed at these times, seed group 1 or 5 should be used as recommended below with a securely tacked mulch. Some appropriate seed selections and suggested planting times is as follows:

Group "1"
Feb. 1 to Mar. 1

Korean or Kobe Lespedeza	50 lb./acre
with	
Rye Grain	120 lb./acre

Group "2"
Mar. 1 to Aug. 15

German Millet	40 lb./acre
or	
Sudangrass	50 lb./acre

Group "3"
Apr. 1 to Jul. 15

Browntop Millet	20 lb./acre
or	
Pearl Millet	20 lb./acre
or	
Sudangrass	40 lb./acre

Group "4"
Aug. 15 to Dec. 15

Rye Grain	120 lb./acre

Note: Seeding dates at elevations above 2,500 feet should begin 1/2 a month later than suggested dates.

Annual lespedeza and weeping lovegrass have demonstrated ability in becoming adaptable to poor conditions, such as well drained, dry cuts and fills. Weeping lovegrass can obtain summer cover quickly but care should be taken when using weeping lovegrass at high seeding rates (above 3 lb. per acre) for it tends to crowd out companion plants, produces a heavy, tough growth which is difficult to mow, and may be a fire hazard in winter.

Seed Application

Seed selected for temporary cover should be applied at a rate not less than the suggested amount above. The seed should be sown uniformly as soon as preparation of the seedbed has been completed by means of a rotary seed spreader, hydraulic equipment, or other satisfactory means. No seed should be sown during windy weather, or when the ground surface is frozen, wet, or otherwise not tillable.

Mulch

Mulching can provide soil stability so that the seed can remain in place long enough to germinate and grow. Mulch should be applied, especially to seedings made in the fall for winter cover or on slopes that exceed 3:1. Refer to the "Mulching" subsection later in this section for guidance.

COMMON TROUBLE POINTS AND SOME CORRECTIVE MEASURES

- Lime and/or fertilizer not incorporated to at least 3 inches; lime and/or fertilizer may be lost to runoff or remain concentrated near the surface where it/they may inhibit germination.

- Mulch rate inadequate or straw mulch not tacked down; this results in poor germination (or failure to germinate) and potential erosion damage.

- Annual rye grass used for temporary seeding; rye grass reseeds itself and makes it difficult to establish a good cover of permanent vegetation.

- Seed not broadcast evenly or application rate too low; either problem results in patchy growth and erosion.

MAINTENANCE

The site should be inspected frequently within the first six weeks of planting to see if stands are uniform and dense and to assure that appropriate moisture levels are being maintained. Provisions should be made to water as needed to penetrate to a depth of six inches. The sodded area should be checked for damage caused by equipment or heavy rains. Damaged areas should be repaired, fertilized, seeded, and mulched. Tack or tie down mulch as necessary.

REFERENCES

North Carolina Sedimentation Control Commission et al., 1988; Tennessee Department of Transportation, 1981; U.S. Department of Agriculture Soil Conservation Service and Institute of Agriculture University of Tennessee, 1990; and Wang and Grubbs, 1990.

PERMANENT SEEDING

DESCRIPTION

Establish permanent vegetative cover on exposed soils where perennial vegetation is needed for long-term protection. Permanent stabilization of the soil helps to assure conservation of soil and water and to enhance the environment. Vegetative cover is the most efficient and economical means of controlling sheet and rill erosion. Damage from erosion or stormwater runoff costs time and money for regrading or other repairs.

WHERE PERMANENT SEEDING IS USED

Exposed soils, such as permanent cut or fill slopes and detention basins, have a potential for causing off-site environmental damage. When the desired permanent seed cannot be applied because of the season, a temporary seed appropriate for the current season may be substituted until appropriate planting season occurs (refer to "Temporary Seeding" subsection of this section for guidance).

BASIC DESIGN AND CONSTRUCTION GUIDELINES

Site Preparation

Each area to be seeded should be scarified, disked, harrowed, raked, or otherwise worked until it has been loosened and pulverized to a depth of approximately 2 to 3 inches. This operation should be performed only when the soil is in a tillable and workable condition. To help prevent the seed from washing away during establishment, the area should be protected with methods such as diversions (see "Diversions" subsection of Section IV). On extremely steep slopes (greater than 3:1), seedbed preparation is not advisable but protective cover with matting or sodding is recommended (see "Erosion Control Matting" or "Sodding" subsections in this section for guidance).

Soil samples should be taken from the site and analyzed for fertilizer and lime requirements. Most plants do well when soil pH is between 6 and 7. Lime and fertilize should be applied as required from soil sample results, else commercial grade 6-12-12 or equivalent fertilizer may be applied at a rate of not less than 1000 lb. per acre (23 pounds per 1,000 square feet) and with agricultural limestone at a rate of not less than 2 tons per acre. Both should be incorporated into the soil to a minimum depth of 3 inches, therefore application during seedbed preparation is suggested. Fertilizer need not be incorporated in the soil as specified above when mixed with seed in water and applied with power sprayer equipment.

Seed Selection

Select appropriate perennial species adaptable to the time of year. Avoid seeding in December or January. If necessary to seed at these times, choose a temporary cover for protection until desired seeding season occurs (see "Temporary Seeding" subsection of this section for guidance) or add appropriate companion plants (such as Korean Lespedeza and/or Rye Grain) and a securely tacked mulch.

Some appropriate seed selections and suggested planting times is as follows (NOTE: the plant in bold type in each mixture is expected to predominate and furnish the permanent cover):

Group "A"
Feb. 15 to Apr. 15
and
Aug. 15 to Oct. 15

Tall Fescue (endophyte infected)	45 lb./acre
with	
White Clover	5 lb./acre

Group "B"
Feb. 15 to Apr. 15
and
Aug. 15 to Oct. 15

Crownvetch	10 lb./acre
with	
Tall Fescue (endophyte infected)	30 lb./acre

Group "C"
Mar. 1 to Apr. 15

Sericea Lespedeza (scarified)	48 lb./acre
with	
Tall Fescue (endophyte infected)	24 lb./acre
with	
Annual Lespedeza	8 lb./acre

Group "D"
July 15 to Mar. 1

Sericea Lespedeza (unhulled)	80 lb./acre
with	
Tall Fescue (endophyte infected)	20 lb./acre

Group "E"
Apr. 15 to June 15

Sericea Lespedeza or **"Appalow" Sericea Lespedeza** (scarified)	48 lb./acre
with	
Bermudagrass (hulled)	6 lb./acre
with	
Annual Lespedeza	6 lb./acre

Group "F"
Apr. 15 to June 15

Sericea Lespedeza (scarified)	48 lb./acre
with	
Weeping Lovegrass	3 lb./acre
with	
Annual Lespedeza	9 lb./acre

Group "G"
Apr. 15 to June 15

Bermudagrass (hulled)	14 lb./acre
with	
Annual Lespedeza	7 lb./acre

Note: Seeding dates at elevations above 2,500 feet should begin 1/2 a month later than suggested dates.

Groups A and B should be used where extra care, fertilization and management can be given. Group B should not be used for traffic areas or areas which will be mowed frequently. Group B is best adapted in Middle and East Tennessee, and in northern half of West Tennessee (see

Vines and Ground Covers under subsection "Trees, Shrubs, Vines, and Ground Cover" in this section for more detail on crownvetch). Groups C through G are suitable for roadbanks and fills. Group G is best adapted in West Tennessee.

Seed Application

Seed selected for permanent cover should be applied at a rate not less than the suggested amount above. The seed should be sown uniformly as soon as preparation of the seedbed has been completed by means of a rotary seed spreader, hydraulic equipment or other satisfactory means. No seed should be sown during windy weather or when the ground surface is frozen, wet, or otherwise not tillable.

Slopes 3:1 or steeper should be overseeded with Sericea Lespedeza at the rate of 15 pounds per acre. Overseeding performed between February 1 and July 1 with Scarified Sericea Lespedeza should be used with an additional 2 pounds per acre of Weeping Lovegrass.

Mulch

Mulch should be applied, especially to seedings made in the fall for winter cover or on slopes that exceed 3:1. Refer to the "Mulching" subsection later in this section for guidance.

COMMON TROUBLE POINTS AND SOME CORRECTIVE MEASURES

- Inadequate seedbed preparation; a well-tilled, limed, and fertilized seedbed is important in vegetative establishment.

- Unsuitable choice of plant materials; select seed appropriate for the season.

- Nurse crop rate too high in mixture; the nurse crop competes and drowns out perennial stock.

- Inadequate mulching; mulch should cover area evenly and should be tacked or tied down well, especially on slopes, ridges, and in channels.

MAINTENANCE

Inspect frequently during the first year of planting to see if stands are uniform and dense. If sparse, patchy areas develop, reevaluate the choice of seed and quantities of lime and fertilizer. If vegetation fails to grow, have the soil tested to determine whether acidity or nutrient deficiency is a problem. Fill or regrade eroded areas, reseed, fertilize, lime, and mulch in a manner to resolve the problem. Tack or tie down mulch as necessary.

Mow bermudagrass areas to remove weeds, but not closer than 2 inches. Tall fescue or weeping lovegrass should not be mowed shorter than 4 inches. Sericea lespedeza should not be mowed until late fall after seed crop is mature. Crownvetch should not be mowed.

REFERENCES

New Jersey Department of Transportation, 1989; North Carolina Sedimentation Control Commission et al., 1988; Tennessee Department of Transportation, 1981; U.S. Department of Agriculture Soil Conservation Service and Institute of Agriculture University of Tennessee, 1990; and Wang and Grubbs, 1990.

TREES, SHRUBS, VINES AND GROUND COVER

DESCRIPTION

Trees, shrubs, vines and ground cover are used to control erosion, help stabilize critical areas, reduce runoff, and enhance the aesthetics and wildlife habitat of disturbed areas.

WHERE THIS PRACTICE IS USED

Trees, shrubs, vines, and ground cover are especially applicable to erodible areas with steep slopes, with rough or rocky terrain, or where mowing and other turf maintenance activities would not be practical nor desirable. They also may be used in shady areas that may present turf establishment problems or where shade, privacy, and/or noise screening are desired.

SELECTION AND INSTALLATION SPECIFICATIONS

Often, selection of a species is based on-site characteristics, climatological conditions, and/or soil characteristics. Areas planted with shrubs or trees should be covered with a suitable mulch or seeded with permanent vegetation to protect the site until the woody plants can become established. Basic installation techniques are as follows:

Mulch

When used, mulch should be applied prior to plantings. Upon planting, trees and shrubs should receive additional mulch until a 4 inch depth bed is produced, covering the entire saucer of individual tree pits and the entire shrub beds.

Trees

<u>Bare-Root Seedlings</u>

Generally, seedlings can be planted from December through March when the soil is not frozen. But on slope cuts, fills, borrow areas, or other places where the topsoil has been removed, transplants are most

successful at elevations above 1,200 feet when performed during March 1 through April 15, while transplants at elevations below 1,200 feet are most successful from February 15 to April 1.

Seedlings should be planted immediately upon delivery. Procedures for planting seedling are illustrated in Figure 2. Do not allow roots to dry out during transplanting. Bare-root seedlings should be handled only while dormant in late winter, in early spring, or after leaf fall in autumn. Store in shaded location out of wind. Lightly moisten seedlings if stored for more than two weeks, but do not add water if seedlings are clay-treated (cover with wet burlap net instead).

Holes to receive these plants are to be of sufficient size and depth to place the roots in a normal position and to allow the plant to be set slightly below grade, leaving a depression to receive and hold water. Water thoroughly upon planting.

Planting Balled-and-Burlapped or Container-Grown Trees

Deciduous trees or pines prefer transplanting in late fall to early Spring (October 1-May 1) and may reject transplanting in the summer or when the ground is frozen. Keep soil around roots moist and bound branches with soft rope to prevent damage during transport.

Balled-and-Burlapped Installation. All balled and burlapped plants should conform to the "American Standard for Nursery Stock," Z60.1, or the latest approved revision. Follow container-grown installation procedure.

Container-Grown installation. The space between the rim and top of the container and the soil line within the container should not be more than 1.5 inches for the 1- or 2-gallon sizes and not more than 2.5 inches for the 5-gallon size. Roots should not protrude through the drainage holes or over the top of the container to the extent that damage would occur during removal from the container.

Dig a hole at least 2 feet greater in diameter than the root ball, keeping the topsoil separate from the subsoil. If the subsoil is high in clay content, the hole should be expanded slightly more. Backfill with 50 percent topsoil and 50 percent approved material excavated from the tree

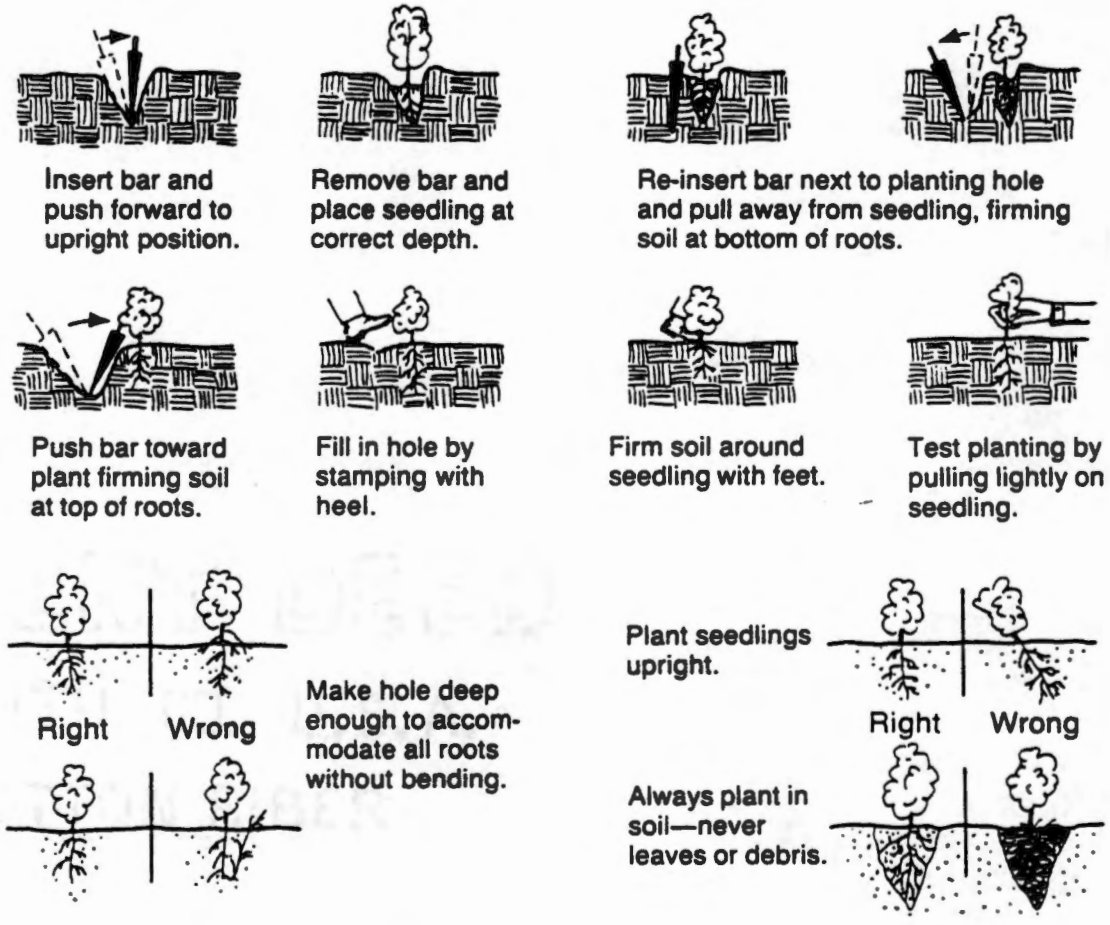


Figure 2. Planting bare-root seedlings.

Source: North Carolina Sedimentation Control Commission, North Carolina Department of Natural Resources and Community Development, and North Carolina Agricultural Extension Service, Erosion and Sediment Control Planning and Design Manual. State of North Carolina Department of Natural Resources and Community Development, Raleigh, North Carolina (1988).

pits and shrub beds, plus fertilizer. Fertilizer for tree planting should be mixed at the rate of 1.5 pounds per inch of tree caliper (diameter).

Firm the soil while backfilling and create a depression around the trunk within the excavated area to hold water as illustrated in Figure 3. Cover the base of the trunk to the same level as before it was removed. Initial watering is suggested at 15 gallons per square yard of plant pit area, rewatering as necessary to keep the roots moist.

Stakes should be at least 6 feet long with dimensions of at least 2 inches x 2 inches, or a minimum diameter of 2.75 inches, or a substitute approved by the Engineer. A minimum of two stakes should be driven firmly into the ground at least 12 inches from the trunk. Secure the tree with Number 12 gauge galvanized wire (or an appropriate substitute), cushioning contact with the tree by using a minimum 1/2 inch diameter new fabric-bearing rubber hose. Note examples in Figure 3.

All deciduous trees should be wrapped starting at the base of the tree working upward, covering the entire trunk to the height of the first branches, as shown in Figure 3. The wrapping should be secure and firmly tied at the top and bottom of the trunk. Tree wrappings should be first quality 4 inch wide rolls of bituminous impregnated tape, corrugated or crepe paper, or equal, specifically manufactured for tree wrapping and having qualities to resist insect infestation.

Commonly Selected Tennessee Species

Native pines (loblolly, Virginia, shortleaf, white, and pitch) and black locust are the major trees that can be used for erosion control and beautification where minimum maintenance is desired. They are adapted for use on selected slope cuts, borrow areas, fills, interchange areas, and medians.

Loblolly pine grows on both wet and dry sites, is the fastest growing of the pines, and produces the greatest amount of mulch. Loblolly pines should not be planted at elevations higher than 2,000 feet.

Virginia pine grows well on poor sites and at elevations up to 2,500 feet. Virginia pine grows well on most sites except deep sands or wet soils.

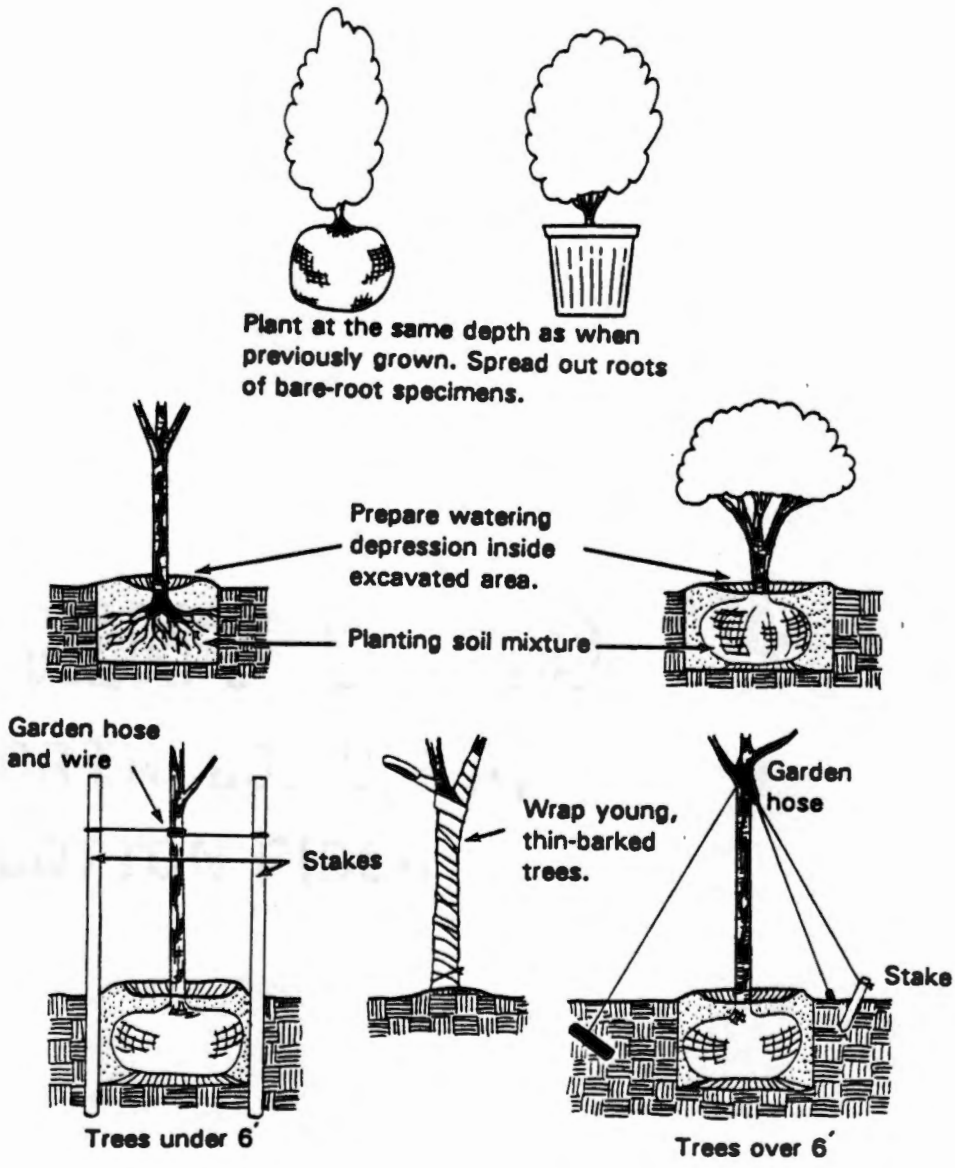


Figure 3. Planting balled-and-burlapped and container grown trees.

Source: North Carolina Sedimentation Control Commission, North Carolina Department of Natural Resources and Community Development, and North Carolina Agricultural Extension Service, Erosion and Sediment Control Planning and Design Manual. State of North Carolina Department of Natural Resources and Community Development, Raleigh, North Carolina (1988).

White pine can be planted on a wide range of soil conditions and is best adapted from the Highland Rim eastward, up to elevations of 4,000 feet.

Shortleaf pine grows at elevations up to 3,300 feet but does not grow well on soils high in clay, with a high pH, or high in calcium. Shortleaf pine has slow initial growth and light needle cast, making it undesirable for planting, but it is fire resistant and may be planted in areas of high fire risk.

Pitch pine is also fire resistant and grows on shallow, sandy and gravelly soils at elevations up to 4,500 feet.

Black locust is an excellent tree for stabilization purposes that grows well from the loess bluffs along the Mississippi Delta to 3,500 foot elevations in the Blue Ridge Mountains. Black locust does not grow well on wet or very dry sites.

Shrubs

Planting shrubs is best done in early fall or early spring. Follow the general procedures for tree installation except planting pits for shrubs should be 6 inches deeper and 6 inches greater on all sides than the plant balls. Details on an ornamental shrub is as follows:

Rose

Rambling, low-growing rose species such as Wichuraiana, Evangeline, Hiawatha, Dorothy Perkins, etc., will provide a very showy, protective cover. These shrubs are slow-growing and may take 4 or more years before their long canes provide cover. Heavy fertilization can result in rapid growth. Plants should be spaced about 3 feet apart and planted on rows at the top and bottom of banks. Tall fescue is suggest for intervening cover until the rose canes dominate. Additional plants may be established after the first growing season by burying the cane tips.

Vines and Ground Covers

The planting of ground cover can be an overplanting of existing grasses or other growing material. Holes to receive these plants should be of sufficient size and depth to accommodate the roots and to allow

the plant to be set slightly below grade, leaving a slight depression to receive and hold water. Two inches of topsoil should be placed under the plant and around the roots. Water thoroughly upon planting.

Most ground covers are planted from container-grown nursery stock. Planting density determines how quickly full cover is achieved; a 1-foot spacing is often suggested for rapid cover, while larger plants may be spaced on 3-foot centers. Planting should be done in early fall or early spring; spring planting is preferred in the mountains. Some common ground covers and their basic installation procedures are as follows:

Crownvetch

Crownvetch is a foliage plant with whitish to purplish-pink blossoms. It grows to a height of about 2.5 feet and is useful on those areas that cannot be mowed or where mowing is to be eliminated or kept to a minimum. Crownvetch is slow in establishment and needs to be planted in existing grasses or provided a companion plant (such as Tall fescue) for proper establishment. Recommended initial seeding is 25% Crownvetch and 75% Tall fescue with total application rates of 40 lb. per acre (10 lb Crownvetch to 30 lb. Tall fescue per acre). When soil test is not available, fertilize at a rate of 12 pounds of grade 0-20-20 fertilizer or equivalent per 1,000 square feet. Apply agricultural limestone at the rate of 100 pounds per 1,000 square feet, distributing fertilizer and limestone uniformly over the area to be planted.

Sprigging of crownvetch should be performed during September-November or April-May and only when the soil is in tillable or workable condition. No crowns should be set during windy weather or when the ground surface is frozen. Crowns should be set at the rate of three sprigs per square yard, setting by means of a tree-planting bar or equal.

Daylily

The old-fashioned tawny orange type (Hemerocallis fulva L.) seems to spread better than some of the newer hybrids. Daylilies may be moved in spring or autumn and planted in hills or rows no more than 2 feet apart. They do best in partial shade, but will grow in full sun if the site is fairly moist. They respond well to water and fertilization.

Kudzu

Kudzu is not often recommended due to its drowning effect on neighboring vegetation, often smothering and killing the adjacent plants. Additionally, kudzu dies off in the winter months which can cause pollution problems to adjacent streams due to large areas of damaged and dead vegetation. However, kudzu is well adapted to the larger and very steep cuts where other vegetation is difficult to establish and grows well on a wide range of soil types, except on extremely heavy clays or soils with poor internal drainage. Kudzu should be mowed annually, after the first killing frost, to help control growth and to minimize winter fire hazard.

Kudzu grows best alone and is very effective in controlling brush growth. Seedlings should be set about 6 feet apart, along or just below the top of the bank and along the toe. On long slopes, space additional rows vertically at about 10 foot intervals. Fertilizer should be grade 0-20-20 and broadcast at 500 pounds per acre. Lime may be applied by mixing approximately 0.4 pounds with the soil at the planting spot prior to planting.

Everlasting Pea and Lathco Flat Pea

Lavender to pink and white blooms with bluish leaves and vines. These plants are slow in providing cover and should be provided a companion plant, such as a thin strand of tall fescue. Seed should be sown in rows on hills in fall or very early spring at a depth of about 2 inches. Seed should be treated with the regular pea inoculant. If inoculant is not available, soil from around the roots of existing plants may be worked into the bed to provide the necessary bacteria. The soil should be well limed and fertilized.

Periwinkle

Low growing, evergreen, creeping vine with dark glossy-green leaves. It grows better in shady location on fairly good soil sites which are not too dry. Single vines or clumps of vines should be planted in 2 foot rows. They will usually cover the ground adequately in 2 years. Transplanting should be done in early spring, fertilized, and well watered (moisten soil to 6 inch depth).

Thrift or Moss-Pink

Pink, white and lavender strains are available. All of them are well adapted to poor, dry banks. Growth is very slow and cannot be spurred on with large amounts of fertilizer (only light annual fertilizer applications is required). They should not be heavily watered. The eventual cover is a very dense protective mat. Plant in early spring on 1- foot spacings.

COMMON TROUBLE POINTS AND SOME CORRECTIVE MEASURES

- Future growth is not taken into consideration; this is a common problem with trees that may grow into utilities, such as wires and pipes, or block vision on roadways. Future growth should be considered prior to planting.

- Cover dies shortly after transplant; a common cause is insufficient initial watering or planting item either too deep, not deep enough, or upside down (most common with seedlings).

- Weeds tend to drown out transplants; applying a heavy layer of mulch around transplants can reduce weed growth.

- Dense growth of kudzu along highway shoulders; such growth may give a false-shoulder effect and may cause motorists to misjudge the width of the road.

- Kudzu tends to grow into unwanted areas; this can be controlled with proper maintenance such as mowing after a killing frost, hand-cutting of runners, or grazing.

MAINTENANCE

Different plant varieties require different maintenance techniques. At a minimum, plan to water new plantings regularly during the extended dry periods encountered. Drip irrigation or sprinkler systems may be a wise investment to protect against the loss of valuable trees. Fertilizer and pest control applications may also be needed from time to time. Some periodic pruning or shaping may be necessary to obtain optimum performance of ornamental varieties.

REFERENCES

New Jersey Department of Transportation, 1989; North Carolina Sedimentation Control Commission et al., 1988; Tennessee Department of Transportation, 1981; and U.S. Department of Agriculture Soil Conservation Service and Institute of Agriculture University of Tennessee, 1990.

MULCHING

DESCRIPTION

Mulching means covering a disturbed soil surface with plant residues or other suitable materials for the purpose of stabilizing the soil surface, retarding erosion, and preserving soil moisture. This is one of the most important, effective, and economical erosion-control practices.

WHERE MULCHING IS USED

Mulching is used on disturbed areas where there is a need to reduce runoff, to reduce loss of soil moisture by evaporation, to reduce seeding damage due to drought or soil frost heaving, and to hold seed, lime, and fertilizers in place. Mulches are useful in protecting bare soils until the correct season for revegetation is reached. Mulches are most suitable for flat or gently sloping areas, but may be anchored to steeply sloping areas by means of nets, mats, or tacifiers.

BASIC DESIGN AND CONSTRUCTION GUIDELINES

Selection

The selection of mulching materials will depend primarily on-site conditions and the material's availability. Organic mulches such as straw, tame or native-grass hay (especially broomsedge), cotton seed hulls, wood or bark chips, and peanut hulls are usually preferred due to their effectiveness and compatibility with the environment. Sericea hay or seed-bearing stems are very desirable mulches.

Mulch Installation

Mulching is generally performed after grading and soil surface preparations are completed. Mulch should cover the area with a uniform layer so that 20-25 percent of the ground is visible. The mulch should be loose enough to allow sunlight to penetrate and air to circulate slowly, but thick enough to partially shade the ground and to reduce erosion. Spread mulch uniformly by hand, with a mulch blower, or with a hydromulcher.

When straw or hay mulch is used on seeded areas it should be spread evenly at an approximate rate of 75 pounds per 1,000 square feet immediately following the seeding operations. When wood fiber mulch is used on seeded areas it should be applied at the rate of 28-35 pounds per 1,000 square feet immediately following the seeding operations. Landscaping mulch should be a standard commercial quality of peat moss weighing approximately 1 ton per 3 cubic yards.

When an area is to receive sprigging of crownvetch, the mulch should be applied prior to planting at the rate of 100 pounds per 1,000 square feet to help prevent weeds from drowning out the sprigs. Tack or tie down mulch when loss to water and/or wind is possible.

Tacifier Installation

Artificial mulching materials or chemical soil additives may be used when additional support is needed. Hay or straw mulch should be held in place by the use of an approved mulch binder such as emulsified asphalt or a guar gum based additive. **Emulsified asphalt** should be applied at the approximate rate of 4 gallons per 1,000 square feet or as specified to hold the mulch in place. A nontoxic, biodegradable **guar gum based additive** that will disperse in cold water to provide a homogeneous lump-free solution which after application will cure to form a water insoluble, semi-porous binder may be used on hay or straw mulch.

When using emulsified asphalt on mulch surrounding sprigs, application rates should not to exceed 0.1 gallon per square yard. Nets may be better suited for critical areas containing sprigs.

When using a mulch binder, cover bridges, guardrails, signs, or other appurtenances if contact with or discoloring of the structures due to the binder is possible.

Netting Installation

Crimping, fiber nets, and mats may be used when additional support is needed. Nets should be used to hold mulch in place on steep slopes or in critical areas. The basic objective of mulch-netting is to provide a stable seedbed for one or two growing seasons, then biodegrade as vegetal matter builds up to produce a healthy cover crop. Apply netting

as stated under the "Erosion Control Matting" subsection of this section or as directed by the manufacture.

COMMON TROUBLE POINTS AND SOME CORRECTIVE MEASURES

- Inadequate coverage; this results in erosion, washout, and poor plant establishment.

- Appropriate tacking agent not applied, or applied in insufficient amount; mulch is lost to wind and runoff.

- Channel grade and liner not appropriate for amount of runoff; this results in erosion of channel bottom. It may be necessary to use stronger protective covers such as mattings (see "Erosion Control Matting" subsection of this section for guidance).

- Hydromulch applied in winter; this results in deterioration of mulch before plants can become established.

MAINTENANCE

Inspect mulch after rainstorms to check for movement of mulch or erosion. If washout, breakage, or erosion occurs, repair surface, reseed, remulch, and/or install new netting as necessary. Continue inspections until vegetation is firmly established.

REFERENCES

Colorado Department of Highways, 1978; North Carolina Sedimentation Control Commission et al., 1988; Oklahoma County Conservation District et al., 1988; Tennessee Department of Transportation, 1981; and U.S. Department of Agriculture Soil Conservation Service and Institute of Agriculture University of Tennessee, 1990.

SODDING

DESCRIPTION

Sodding provides a quick, protective cover to prevent soil erosion and/or to enhance aesthetics on disturbed areas.

WHERE SODDING IS USED

- Any area sensitive to appearance or any disturbed areas that need stabilization such as slopes, swales, detention structures, or other critical locations.

- Where quick protective measures are necessary due to potential problems caused by erosion, such as sedimentation damage or high repair cost, or where it is desirable to avoid leaving an area unattractive in appearance for a long time.

- In areas where the season is not favorable for proper establishment with seeding.

- In drainageways subject to concentrated flows, where establishment of cover with seeds is difficult due to the lag time between installation and stabilized growth.

- Around drop inlets or along the sides of paved drainageways to help keep these areas free of mulch, seed, and mud.

BASIC DESIGN AND CONSTRUCTION GUIDELINES

Site Preparation

The area to be sodded should be brought to the lines and grades shown on the plans. The area should be loosened to a depth of not less than 1 inch with a rake or other device. When necessary, the ground should be sprinkled until saturated to a minimum depth of 1 inch and kept moist until the sod is placed.

Fertilizer and lime should be applied uniformly to the prepared surface immediately before placing sod. A soil test can determine efficient application rates. When soil test is not available, fertilize with 10-10-10 or equivalent applying at a rate of 12 pounds per 1,000 square feet. Agricultural limestone should be applied at a rate of 100 pounds per 1,000 square feet.

Sod Requirements

Sod should be certified by the Tennessee Department of Agriculture prior to removal for sale or movement or meet the "New Sod" requirements of this section.

All sod should be cleanly cut in strips having a reasonable uniform thickness of not less than 1 inch, reasonable uniform width of no less than 8 inches, and a minimum length of 12 inches.

New Sod

New sod should consist of live, dense, well-rooted growth of permanent grasses, free from Johnson grass, nutgrass, and other obnoxious grasses or weeds, well-suited for the intended purpose and for the soil in which it is to be planted.

Removing and Resetting Sod

Sod removed from such areas as lawns, yards, lots, etc., should be cut, handled, and stored so that the sod can be reset in the same locations from which it was removed. Unless reset is performed immediately after cutting, sod should be stacked in piles and kept moist until reset. Sod should be reset within 7 days after removal.

Sod Application

Sod should be set or reset only when the soil is moist and favorable to growth. Sod should not be placed on frozen soil. No sod should be placed between December 1 and February 1, unless weather and soil conditions are considered favorable.

Sod should be placed as soon as practical after removal from the point of origin and should be kept in a moist condition during the interim.

Care should be taken when laying sod adjacent to structures, ditch paving, sidewalks, etc., so that water does not pond but is allowed to flow as designed. On urban projects the sod should be placed on all newly graded cut and fill slopes as work progresses to prevent damage to adjacent facilities and property due to erosion. Care should be exercised to retain the soil on the root system during excavating, hauling, and planting. All sod should be in an acceptable condition upon delivery and placement at the work site. Sod damaged by heat or dry conditions should not be used.

The sod should be carefully placed by hand on the prepared ground surface with the edges in close contact and, where possible, in a position to break joints such as a brick-like pattern (see Figure 4). Each strip of sod laid should be fitted into place, thoroughly wetted, and rolled with an approved roller or hand-tamped to ensure proper contact. The sod strips should be installed with their longest dimension perpendicular to the flow path (see Figure 5) and should not overlap or be stretched. On slopes of 2:1 or steeper, pinning or pegging may be required to hold the sod in place.

When sod is used in waterways, each strip should be stapled once in the center and at each corner (as indicated in Figure 5), or as specified by the Engineer. Jute netting may be pegged over the sod for further protection against washing out during establishment.

COMMON TROUBLE POINTS AND SOME CORRECTIVE MEASURES

- Sod laid on poorly prepared soil or unsuitable surface; grass dies because it is unable to root.

- Sod not adequately irrigated after installation; lack of water may cause root dieback or grass may not root properly because of dry conditions.

- Sod not anchored properly; unanchored sod may be loosened by runoff.

- Ponding of water on sod; improperly graded areas that cause pools of water to form can cause damage due to drowning of the sod.

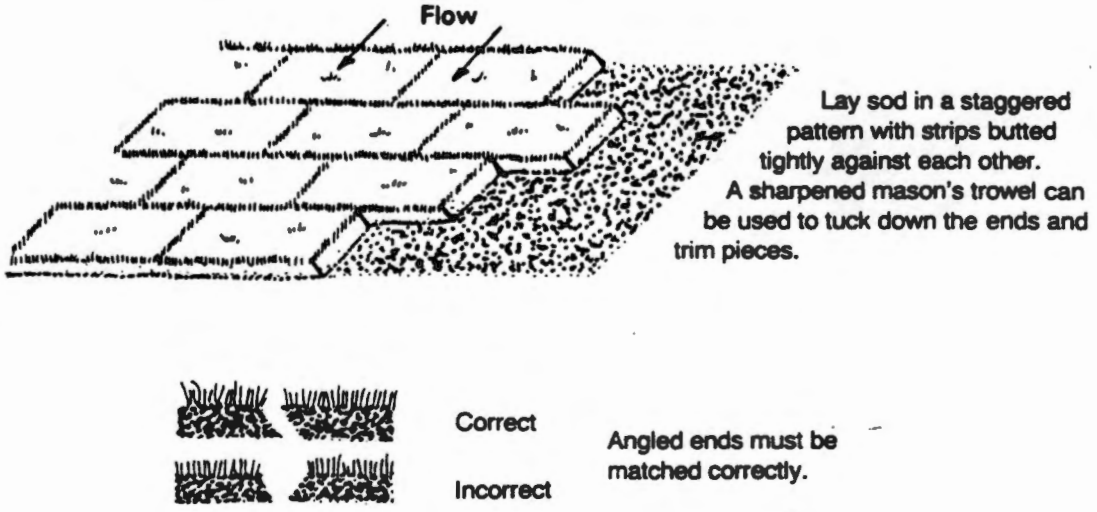


Figure 4. Detailed installation of grass sod.

Source: North Carolina Sedimentation Control Commission, North Carolina Department of Natural Resources and Community Development, and North Carolina Agricultural Extension Service, Erosion and Sediment Control Planning and Design Manual. State of North Carolina Department of Natural Resources and Community Development, Raleigh, North Carolina (1988).

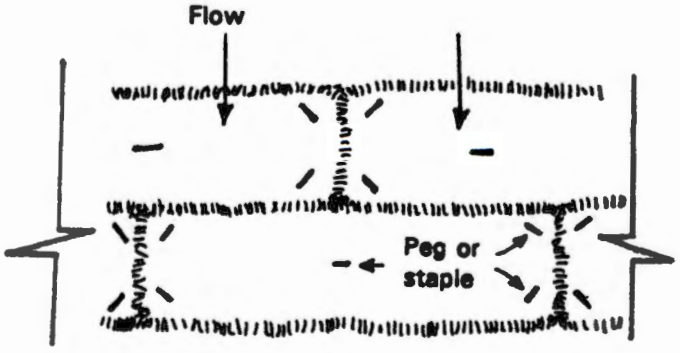


Figure 5. Suggested sodding staple pattern for waterway application.

- Equipment allowed to travel over sodded area or materials are stored on sod; the sod may become damaged or destroyed.

MAINTENANCE

The sod should be watered for the first two weeks and should be keep moist until it is fully rooted. The sod should not be mowed until it is well-rooted (usually 2-3 weeks) nor in a manner that will remove more than one-third of the shoot. Sod should not be mowed shorter than 2-3 inches in height.

Upon 14 days from application of sod and prior to the final watering, ammonium nitrate should be applied at the rate of 3.5 pounds per 1,000 square feet. Permanent, fine turf areas may require yearly fertilization maintenance. Fertilizer should be applied in late spring to early summer for warm-season grass, while cool-season grass should be treated in late winter and again in early fall.

REFERENCES

North Carolina Sedimentation Control Commission et al., 1988; Tennessee Department of Transportation, 1981; and Virginia Soil and Water Conservation Commission, 1980.

EROSION CONTROL MATTING

DESCRIPTION

The placing and securing of either jute mesh, excelsior matting, erosion control fabric, or other approved matting is used to prevent erosion on previously shaped and seeded drainage channels, slopes, or other critical areas. The basic objective of erosion control matting is to provide a stable seedbed for one or more growing seasons (though some may be designed to last longer in extreme conditions), then to biodegrade as vegetal matter builds up to produce a healthy cover crop.

WHERE EROSION CONTROL MATTINGS ARE USED

Erosion control matting can be used in any area subjected to erosive actions such as newly graded slopes, detention structures, and stream banks where moving water is likely to wash out new vegetative plantings.

Erosion control mattings are quite effective in controlling erosion on steep slopes and in ditches where design flow may exceed 3.5 feet per second. Mattings are especially advantageous on high altitude projects where growing seasons are very short and the soil erosion potential is high.

BASIC DESIGN AND CONSTRUCTION GUIDELINES

Site Preparation

The areas to receive the erosion control matting should have been previously shaped, fertilized, and seeded. A smooth surface free of depressions and eroded areas that would allow water to collect or flow under the matting should be required. Unless otherwise specified, the soil should be left with a loose surface after seeding.

Materials

Fasteners

Fasteners could be constructed from a nail with a 1 to 2 inch washer, a wooden stake, a No. 11 gauge new steel wire formed into a "U" shape, or any other appropriate material capable of securely holding the matting. Staples should be 6-10 inches long, with the longer staples used on loose, unstable soils. In areas that are to be mowed it is often desirable to use stakes that will not cause damage to mowing equipment, such as wooden pegs.

Erosion Control Matting

A wide range of mattings are currently on the market. Selection will depend on-site conditions and overall desired results. For example, a 2-3 inch mesh netting may be sufficient to hold mulch in place on a gently sloping terrain while a more durable excelsior matting may be necessary for vegetation establishment within a drainage channel. Ensure the selected matting will be sufficient for the desired result.

Installation

Numerous variations of erosion control mattings currently exist. Basic application guides for a few most commonly used erosion control mattings are listed below.

Erosion Control Fabrics

Erosion control fabrics, such as nettings, are especially useful when applied over mulch, over sod, and/or in low volume and velocity ditches. Erosion control fabrics may be applied perpendicular or horizontal to the contour lines depending upon the slope characteristics, but should be placed in the direction of the water flow in ditch installation.

Fabric should be placed approximately horizontal on slopes that are less than 2:1 and less than 20 feet long or in situations where one width of the fabric will cover the entire length.

Fabric should be placed approximately perpendicular on slopes greater than 2:1, or if the length of the slope exceeds the width to be

covered, or on slopes with excessive runoff from adjacent areas regardless of the degree or length of the slope.

Prior to netting placement, a 4 inch anchor trench should be dug at the top and toe of the slope with the top trench placed 1 foot back from the crown, or a berm over which the fabric can be carried should be used.

For perpendicular application the erosion control fabric should be tucked into the top trench, stapled, and covered with topsoil. The material is then unrolled and stapled as the work proceeds. The vertical strips should have a 4 inch overlap. The material should be in the trench at the bottom of the slope.

For horizontal application, work must proceed from the bottom toward the top of the slope with a 4 inch overlap. After cutting, the material should be folded under 3-4 inches at the end, stapled, and covered with topsoil.

The netting should not be stretched, but allowed to lay smoothly and loosely on the surface.

Staples should be placed 9 to 12 inches apart in the trenches and along horizontal lap joints. For perpendicular applications, a 3 foot interval is sufficient along the laps. Staples should be placed in three alternating rows at approximately 3 foot intervals along the length of the inner portions of the material. Extra staples on 9 to 12 inch centers should be used around the mouths of culverts and flumes.

Where extremely erodible soil is anticipated, an erosion stop should be placed at the midpoint of the slope. The material should be stapled every 9 to 12 inches along the center of the erosion stop, filled with topsoil, and tamped thoroughly.

Excelsior Matting

Matting should be unrolled in the direction of flow with edges and ends butted snugly against each other. Anchor ditches should be required on the upgrade side of the fabric. When unrolled, the netting should be on top and the fibers should be in contact with the soil.

Staples should be driven vertically into the ground, anchoring the mat firmly to the soil, and driven flush with the surface of the mat. Slopes flatter than 4:1 should be stapled no more than 5 feet apart on all edges and 1 foot apart at all joints and ends. On all slopes steeper than 4:1 and in all ditches, three staggered rows of staples should be spaced 2.5-3 feet apart. Additionally, all joints and ends should be spaced not more than 6 inches apart. The spacing of staples may be modified to fit the conditions as directed by the manufacture.

Jute Mesh

When jute mesh is to be used, the upslope end should be in a trench at least 6 inches deep with the soil firmly tamped against it and unrolled in the direction of the water flow. Areas exposed to more than normal flow of water should be anchored around the edges as well. The matting should not be stretched but should be spread evenly and smoothly so that it is in close contact with the ground at all points.

Successive strips of matting should overlap at least 6 inches at the ends, with the upgrade strip on top. Parallel strips of matting should overlap at least 4 inches.

Check slots should be spaced not more than 50 feet from an end slot or another check slot. Check slots should be placed with a tight fold of matting anchored at least 6 inches vertically into the ground and tamped firmly.

Fasteners should be driven vertically into the ground to tightly hold the matting flush to the ground. Staples should be spaced not more than 4 feet apart in three rows for each strip, with one row along each edge and one row alternately spaced in the center. On overlapping edges of parallel strips, staples should be spaced not more than 2 feet apart. All anchor, junction, and check slots staples should be spaced not more than 6 inches apart.

After the matting is stapled into place, it should then be pressed into the ground with a light lawn roller or other appropriate means. Figure 6 illustrates jute mesh mattings installation.

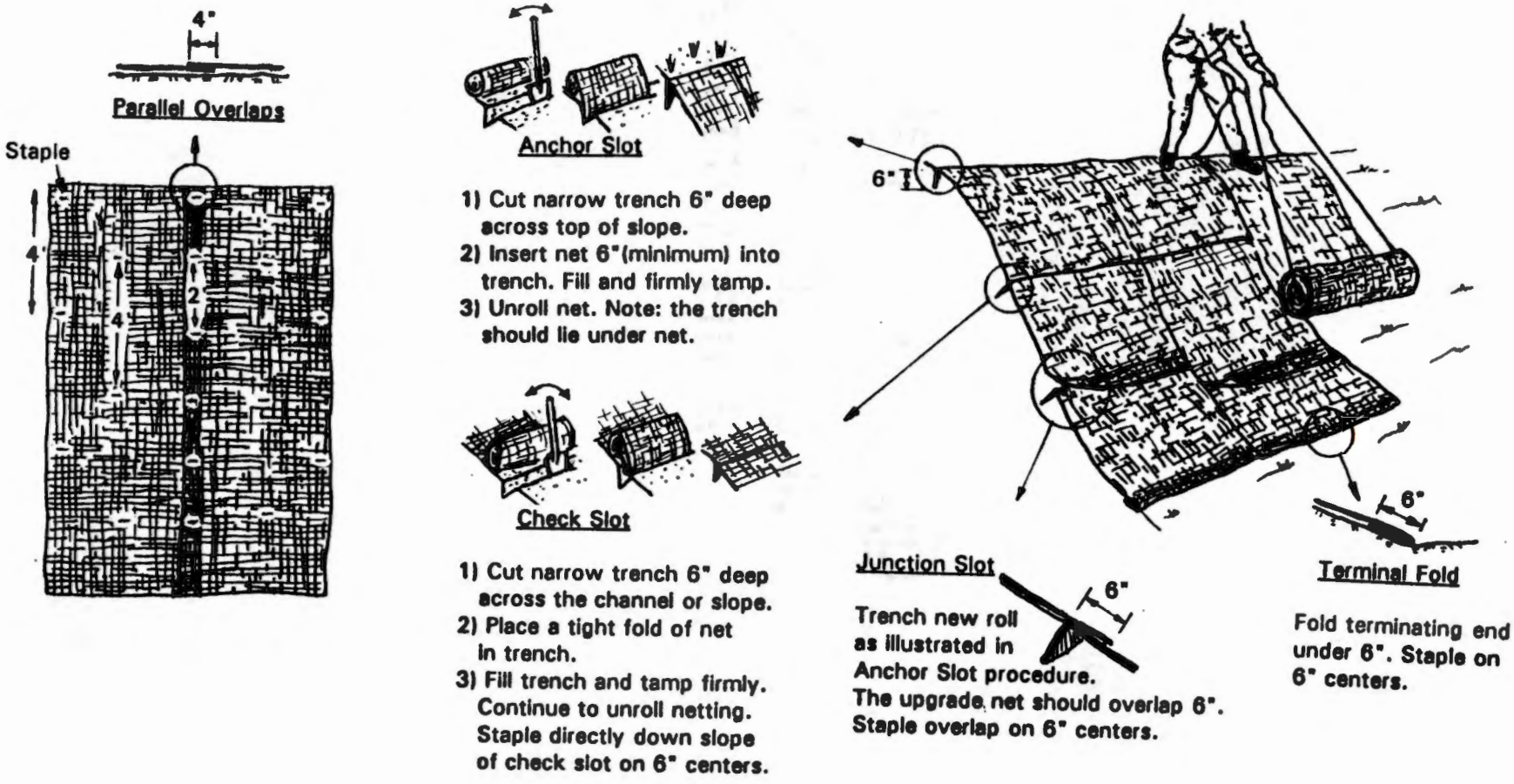


Figure 6. Application of jute mesh.

Other Forms of Erosion Control Mattings

Other forms of erosion control mattings should be installed as specified on the plans or as directed by the manufacture.

COMMON TROUBLE POINTS AND SOME CORRECTIVE MEASURES

- Inadequate coverage; inadequate coverage results in erosion, washout, and poor plant establishment.

- Appropriate staple spacing not applied, or applied in insufficient amount; seed, topsoil, and mulch is lost to wind and runoff.

- Channel grade and liner not appropriate for amount of runoff; this may result in erosion of the channel bottom. Modification may be necessary.

MAINTENANCE

Inspect erosion control mattings after rainstorms to check for movement of topsoil, movement of the mulch, or erosion. If washout, breakage, or erosion occurs, repair surface, reseed, resod, remulch and/or replace topsoil, and install new netting. Continue inspections until vegetation is firmly established.

REFERENCES

Colorado Department of Highways, 1978; North Carolina Sediment Control Commission et al., 1988; and Tennessee Department of Transportation, 1981.

TOPSOIL

DESCRIPTION

Topsoil from the construction site should be preserved and used to enhance the final site stabilization with vegetative cover.

WHERE TOPSOIL IS USED

Where earth disturbing activities expose subsoil layers that are poorly suited to support vegetative growth. Preservation and reuse of native topsoil helps improve the success rate of new vegetation. This practice is particularly useful for sites where turf or ornamental plants will be established after construction is complete. In some instances, when no suitable material is available on-site, it may be necessary to import needed topsoil.

BASIC REQUIREMENTS

Topsoil material should be a natural, friable, fertile, fine sandy loam possessing the characteristics of representative topsoil in the vicinity that produce heavy growths of vegetation. The topsoil should be free from subsoil, noxious weeds, stones larger than 1 inch in diameter, lime, cement, ashes, slag, or other deleterious matter. Topsoil should be well drained in its original position and free from toxic quantities of acid or alkaline elements.

Prior to stripping away topsoil, make certain that all downslope sediment control practices (such as detention ponds) are in place and operational. Strip topsoil only from those areas that will be disturbed by excavation, filling, road building, or compaction by equipment. Normally, 4-6 inches are stripped for topsoil use, but depth can vary with each site.

When stockpiling topsoil, locate the topsoil where it will not erode, block drainage, or interfere with work on the site. On large sites, respreading is easier and more economical when topsoil is stockpiled in small piles located near areas where it will be used. Protect topsoil stockpiles with temporary seeding or with permanent seed if plans do not call for use within 7 weeks.

Before topsoil is applied to the site, subsoils should be graded and loosened by disking to a depth of 2 inches. This will help ensure bonding of the topsoil with the subsoil. Topsoil should be evenly spread to a minimum depth of 4 inches. When the site has been excavated down to rock such as sandstone or shale, 8-12 inches of topsoil is recommended for good plant growth. Topsoil should not be applied to slopes steeper than 2:1 to avoid slippage, nor to a subsoil of highly contrasting texture.

After spreading, topsoil should be minimally compacted to improve contact with the subsoil layer. Topsoil should not be placed when site conditions are wet, muddy, or frozen as this may interfere with proper spreading and bonding. Newly applied topsoil should be immediately protected with temporary or permanent erosion control measures to prevent erosion damage and loss of valuable topsoil materials.

Compost from solid waste disposal facilities and/or wastewater treatment plant sludge is sometimes mixed with or used as topsoil. Appropriate personnel and research literature should be consulted for proper guidance when employing the use of such.

COMMON TROUBLE POINTS AND SOME CORRECTIVE MEASURES

- Topsoil washes away; erosion control practices were not provided.

- Uncertainty on quality of topsoil; if doubts exist, take a sample to the county agricultural agent (extension service) for examination.

MAINTENANCE

Inspect areas of newly applied topsoil frequently until vegetation is reestablished so that erosion and damage or vegetation failure can be quickly remedied.

REFERENCES

North Carolina Sedimentation Control Commission et al., 1988; Oklahoma County Conservation District et al., 1988; and Tennessee Department of Transportation, 1981.

SECTION III

BASIC SEDIMENT BARRIERS

STRAW BALE BARRIER

DESCRIPTION

A straw bale barrier is a temporary entrenched and anchored barrier used to intercept sediment-laden runoff and to provide some retention of sediment from small drainage areas. A straw bale barrier can be used to promote sheet flow and to reduce runoff velocity, thus reducing erosion and improving water quality. These barriers are not meant to filter water, but instead work by pooling the sediment-laden water via a damming effect which allow some settlement of the sediment before being slowly released. Better settlement of the suspended sediments is achieved when a barrier is placed on flat, small sloping contours which allows larger pool development than from a barrier placed on relatively steep contours which creates smaller pools with shorter holding times. When limited to steep terrain, placing several rows of barriers along the contours can create several small holding pools which can increase the efficiency.

WHERE STRAW BALES ARE USED

Straw bales can be used for slope protection in disturbed areas to control sheet and rill erosion, in minor swales or ditches to help trap sediment-laden runoff and slow velocities, around or downslope of soil stockpiles, and/or around storm drains and inlets (see "Inlet Protection" subsection of Section IV for inlet drainage protection guidance).

BASIC DESIGN AND CONSTRUCTION GUIDELINES

An average straw bale should be 30 inches in length, weigh at least 50 pounds, and contain 5 cubic feet or more of material. The expected in place life span is normally 3 months, therefore straw bales must be replaced or a new barrier placed directly upslope of the old when a barrier is required for longer time periods. Guidelines are as follows:

Slope Protection

Recommended maximum size of the drainage area is 0.25 acres per 100 feet of straw bale barrier fence length; the maximum length of slope behind the fence is 100 feet; and the maximum slope length for given slopes is as follows:

Slope	Slope Length
< 2%	100 feet
2 to 5%	75 feet
5 to 10%	50 feet
10 to 20%	25 feet
> 20%	15 feet

Channel/Storm Drain Application

Straw bale barriers may be used for areas draining 1 acre or less and/or where the flow rate of runoff is not expected to exceed 2 cubic feet per second.

See "Check Dam" subsection of Section IV for additional guidance on channel application.

See "Inlet Protection" subsection of Section IV for inlet drainage protection employing straw bales.

Design/Installation Guidance

A barrier should be placed along a contour with ends installed upslope until at a slightly higher elevation than the top of the bales along the contour.

A 4 to 6 inch deep trench should be excavated to the length of the barrier and the width of the bale, as shown in Figure 7. Excavated material is to be placed on the upstream side of the trench. Wire or string-bound bales containing a minimum 5 cubic feet of either hay or straw are placed in the trench and should be anchored by two 2 x 2 wooden stakes or rebar steel pickets driven through the bale into the underlying soil at a slight upstream angle, as illustrated in Figure 8, to help prevent the bale from overturning. The first stake should also be driven slightly toward the previously laid bale to force them together.

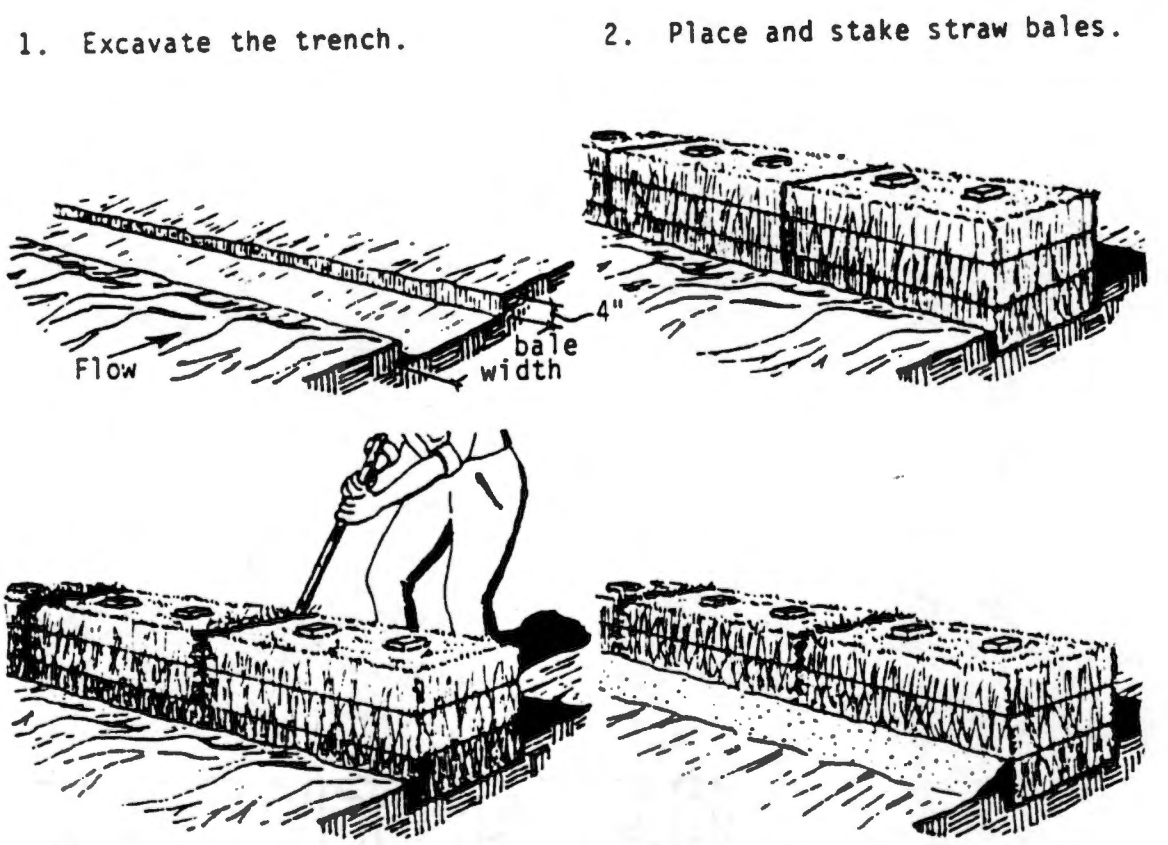


Figure 7. Construction of a straw bale barrier.

Source: Virginia Soil and Water Conservation Commission, Virginia Soil and Erosion Control Handbook, Second Edition. Virginia Soil and Water Conservation Commission, Richmond, Virginia (1980).

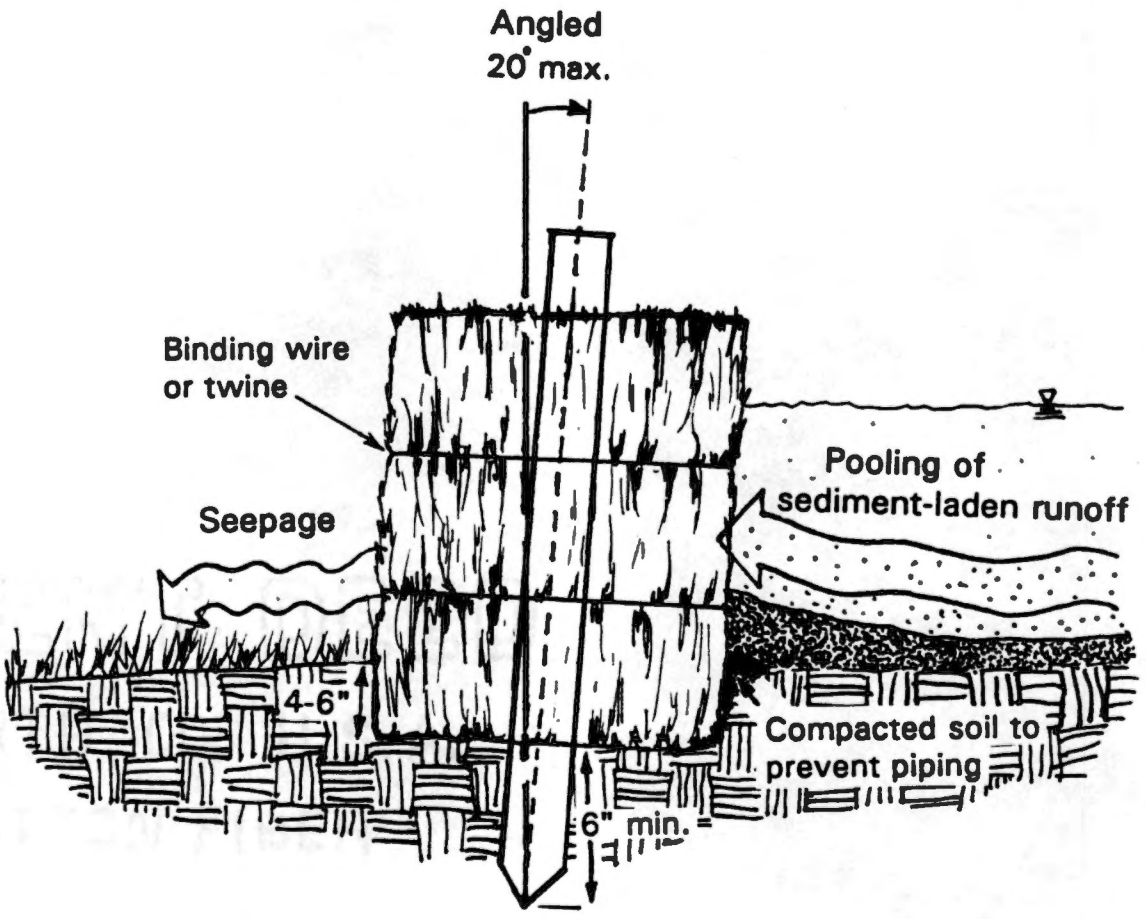


Figure 8. Cross-section of a properly installed straw bale.

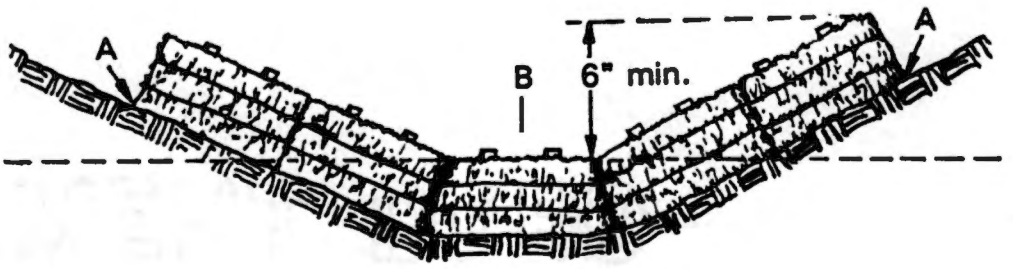
Spacing between the bales should be tightly chinked with loose straw (note Figure 7). The excavated soil can now be backfilled firmly against the upslope side and compacted to help prevent undercutting.

All straw bales should be installed such that the bindings are above the trench as illustrated in Figures 7 and 8. If bindings are placed flush with the surface, they will quickly degrade and cause possible failure to the barrier.

When using straw bale check dams in swales or ditches, the barrier should be placed perpendicular to the contour. The same installation procedure is followed with the barrier extended up the sides of the ditch until the tops of the end bales are higher than the top of the lowest middle bale, as illustrated in Figure 9. This will prevent scour due to flow around the ends of the barrier.

COMMON TROUBLE POINTS AND SOME CORRECTIVE MEASURES

- Drainage area too large; break up into smaller areas.
- Too much sediment accumulation allowed before clean out; too much sediment accumulation may cause barrier to fail.
- Upstream slope too steep or too long; break up length with additional rows of barriers.
- Undercutting occurs; bales were not trenched at least 4 inches or compacted properly.
- Loose spots or spacings not tightly chinked with loose hay; this may result in insufficient trap efficiency.
- Bales located across a drainageway; flow may be in excess of bales' capacity.
- Erosion around barrier ends due to endpoints being lower than top of temporary pool elevation; reshape ends to elevation above pool level.



Points A should be higher than point B a minimum of 6"

Figure 9. Proper placement of a straw bale barrier in a drainageway.

MAINTENANCE

Bale barriers should be inspected immediately after each rainfall or daily during periods of prolonged rainfall. Damaged bales and undercutting or flow channels around the ends of barriers should be repaired or corrected as soon as possible. Sediment deposits should be removed after each rainfall, and accumulations should be removed when they reach one-half the height of the barrier.

REMOVAL

After all sediment producing areas have been permanently stabilized, all sediment accumulation at the barrier trap should be removed, and all excavation should be backfilled and properly compacted. Smooth the site to blend with the terrain or as specified on plans.

REFERENCES

Maryland Department of the Environment et al., 1983; Oklahoma County Conservation District et al., 1988; Tennessee Department of Transportation, 1981; U.S. Department of Agriculture, 1987; and Virginia Soil and Water Conservation Commission et al., 1980.

SILT FENCE BARRIER

DESCRIPTION

A silt fence is a temporary barrier of geotextile fabric (filter cloth) used to intercept sediment-laden runoff from small drainage areas. A silt fence can be used to promote sheet flow, to reduce runoff velocity, and to help retain transported sediment on the site, thus reducing erosion and enhancing water quality. These barriers are not meant to filter water, but instead work by pooling the sediment-laden water via a damming effect which allow some settlement of the sediment before being slowly released. Better settlement of the suspended sediments is achieved when a barrier is placed on flat, small sloping contours which allows larger pool development than from a barrier placed on relatively steep contours which creates smaller pools with shorter holding times. When limited to steep terrain, placing several rows of barriers along the contours can create several small holding pools which increases the efficiency.

TYPES OF SILT FENCE BARRIERS

There are two general types of silt fence barriers -- filter barriers and silt fences. **Filter barriers** are inexpensive structures composed of burlap or standard weight synthetic filter fabric attached to wooden or steel stakes. Flow rates through burlap filter barriers are slightly slower and sediment trapping efficiency is significantly higher than for straw bale barriers. Average life is dependent on the ultraviolet inhibitor added, but is typically 3 months.

Silt fences have slower flow rate but significantly higher sediment trapping efficiencies than the burlap fabric. Silt fences are very effective in sheet flow conditions and usually ineffective with concentrated flows. Woven and nonwoven synthetic fabrics are available. Woven fabric is generally stronger than nonwoven fabric and usually does not require the additional support of a wire mesh. Average life is dependent on the ultraviolet inhibitor added, but is usually 6 months.

WHERE SILT FENCES ARE USED

Silt fences are commonly placed at the bottom of a disturbed slope, around or downslope of soil stockpiles, or adjacent to streams and/or ponds. Silt fences have a lower failure rate than straw bale barriers, but are more expensive. Silt fences can be used for slope protection, in minor swales or ditches, and/or around storm drains and inlets (see "Inlet Protection" subsection of Section IV for inlet drainage protection guidance).

BASIC DESIGN AND CONSTRUCTION GUIDELINES

Slope Protection

The maximum size of the drainage area should be 0.25 acres per 100 feet of fence length; the maximum length of slope behind the fence is 100 feet; and the maximum slope length for given slopes is as follows:

Slope	Slope Length
< 2%	100 feet
2 to 5%	75 feet
5 to 10%	50 feet
10 to 20%	25 feet
> 20%	15 feet

Channel/Storm Drain Application

Filter fences (burlap filter fabric or equivalent) may be used in stream channels and storm drains for areas draining no more than 1 acre and/or where the flow rate of runoff is not expected to exceed 1 cubic feet per second. **They are not for use in perennial channels.**

See "Inlet Protection" subsection of Section IV for inlet drainage protection employing silt fences.

Design/Installation Guidelines

- A barrier should be placed along a contour with ends installed upslope until at a slightly higher elevation than the top of the barrier along the contour.

- The height of the filter fabric silt fence should be at least 1.25 feet and not exceed 3 feet.

- The filter fabric should be purchased in a continuous roll and cut to the length of the barrier to avoid the use of joints. When unavoidable, overlap should extend over a minimum of two stakes with extra care in fastening occurring at the joints to prevent flow bypass.

- Wood posts should have a minimum cross sectional area of at least 3 square inches. Steel posts can be standard T or U sections weighing no less then 1.33 pound per foot, with projections for fastening wire mesh. Posts should be at least 5 feet long and driven at a slight upstream angle into the ground to a minimum of depth of 18 inches. Note Figure 10.

- When a wire mesh support fence is used, the wire should be a minimum 14-gauge with maximum mesh spacing of 6 inches and must be securely fastened to the upstream side of the post.

- If the filter fabric is of extra-strength quality, no wire mesh support is required and maximum post spacing is 6 feet. Otherwise, wire mesh is required with a maximum post spacing of 10 feet.

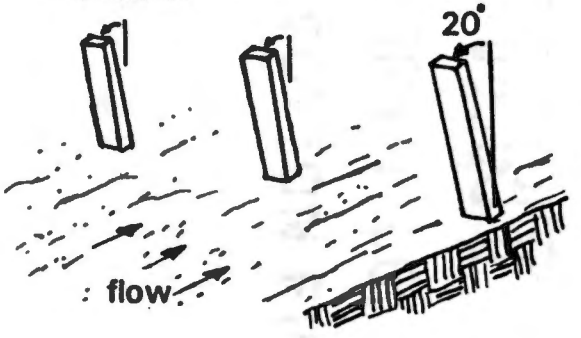
- A trench is excavated at least 4 inches deep and 4 inches wide along the line of the support posts and upstream from the barrier, as illustrated in Figure 10.

- The filter fabric and wire mesh (when applicable) is stapled or wired to the post then placed a minimum of 8 inches into the trench. Staples should be a 17 gauge wire and 1/2 inch long.

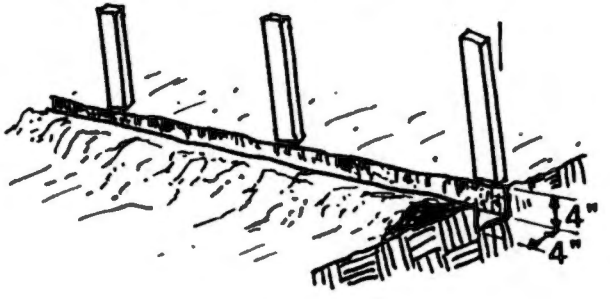
- The trench is backfilled and soil compacted over the filter fabric. Note the completed cross section illustrated in Figure 11.

- When a filter barrier is constructed across a ditch or swale, the barrier should be of sufficient length to eliminate end flow, and the plan configuration should resemble a horseshoe with the ends pointing upslope, as shown in Figure 12.

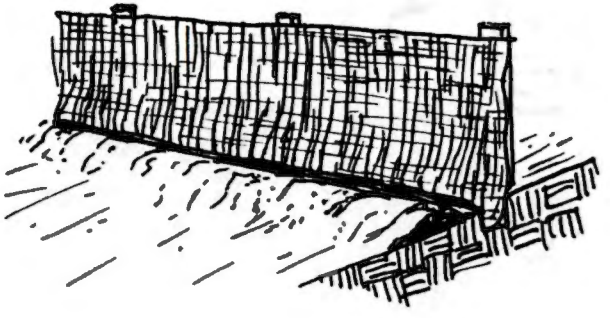
1. Set stakes, angled not more than 20° toward the direction of flow.



2. Excavate a 4"x4" trench upslope along the line of stakes. When necessary, attach wire fencing.



3. Staple filter material to stakes and extend it into the trench.



4. Backfill and compact the excavated soil.

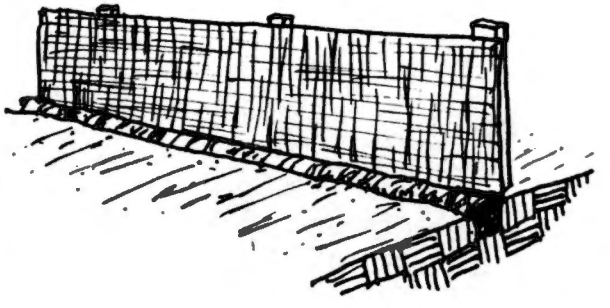


Figure 10. Construction of a filter barrier.

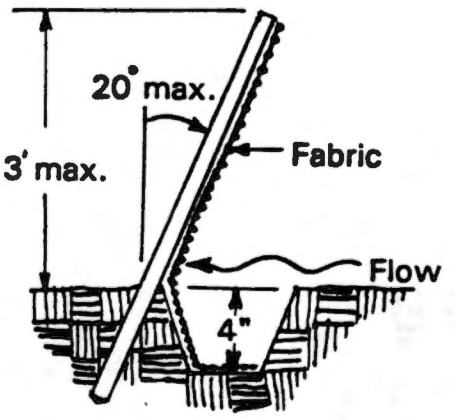
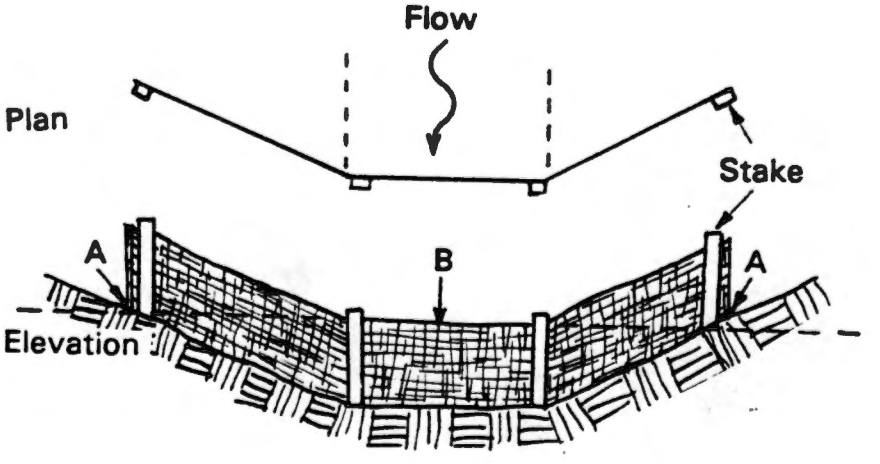


Figure 11. Cross section of a properly installed silt fence.



Points A should be higher than point B

Figure 12. Proper placement of a filter barrier in a drainageway.

- An excavated silt trap may be desirable when large amounts of sediment are expected or cleanout of sediment accumulation is restricted due to site conditions (see "Temporary Sediment Trap" subsection of Section V for guidance).

- Note: Some manufactories will recommend rather than trenching the silt fence, laying the typically entrenched extension flat on the surface, pointing upgradient of flow and covering with soil. Although this may work in some incidents, this technique is not recommended because undercutting is more likely to develop than with trenching.

SPECIFICATIONS

Some basic, standard specification to look for is as follows:

Physical Properties	Requirements
Filtering Efficiency	85% (minimum)
Tensile Strength at 20% Elongation (maximum)	Standard Strength -- 30 lb/linear-in (minimum)
	Extra Strength -- 50 lb/linear-in (minimum)
Slurry Flow Rate	0.3 gal/sq-ft/min (minimum)

COMMON TROUBLE POINTS AND SOME CORRECTIVE MEASURES

- Drainage area too large; break drainage area up into smaller areas.

- Too much sediment accumulation allowed before clean out; too much sediment accumulation may cause barrier to fail.

- Upstream slope too steep or too long; break up slope length with additional rows of barriers.

- Fence not adequately supported; this may result in failure.

- Fence located across a drainageway; flows may be in excess of the silt fence's capability.

- Undercutting occurs; fence was not buried at least 8 inches or the trench was not backfilled and compacted properly.

- Erosion around barrier ends due to endpoints being lower than top of temporary pool elevation; reshape ends to elevation above pool level.

MAINTENANCE

Silt fences should be inspected immediately after each heavy rainfall event or daily during periods of prolonged rainfall. Damaged fences, undercutting, or flow channels around the ends of barriers should be repaired or corrected immediately. Sediment deposits should be removed after each significant rainfall event. Accumulations should be removed when they reach one-half the height of the fence or a new fence placed immediately upslope of the previous. Sediment should be properly disposed to prevent its entry into any watercourse.

REMOVAL

After all sediment producing areas have been permanently stabilized, all sediment accumulation at the barrier trap should be removed, and all excavations should be backfilled and properly compacted. Smooth the site to blend with the terrain or as specified on plans.

REFERENCES

Kouwen, 1990; Maryland Department of Transportation et al., 1989; North Carolina Sedimentation Control Commission et al., 1988; Oklahoma County Conservation District et al., 1988; Tennessee Department of Transportation, 1981; U.S. Department of Agriculture, 1987; Virginia Soil and Water Conservation Commission, 1980; and Wang and Grubbs, 1990.

BRUSH BARRIER

DESCRIPTION

A brush barrier is a temporary barrier used to control sediment transport by using the residue materials available from clearing and grubbing.

HOW AND WHERE BRUSH BARRIERS ARE USED

Brush barriers may be used below disturbed areas subject to sheet and rill erosion, where enough residue material is available for construction of the barrier.

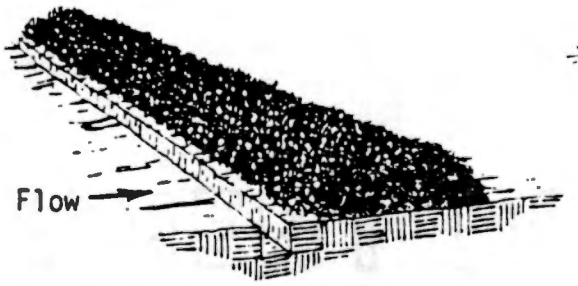
BASIC DESIGN AND CONSTRUCTION GUIDELINES

- Brush should be cut and windrowed approximately 10 feet from the toe of the slope. The brush barrier should be packed densely and should be a minimum of 4 feet high before compressing. This may be accomplished during clearing and grubbing by having equipment push the brush, tree trimmings, shrubs, stones, root mats, and other materials into a mounded row on the contour. Logs placed within the barrier, parallel to the toe, can help reduce failures.

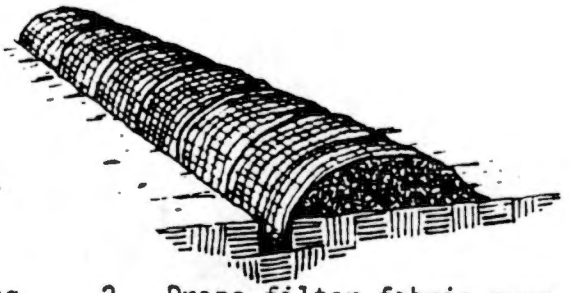
- A brush barrier may be compressed by running a dozer along the top of the windrow. The compressed barrier should be 3 to 5 feet high and 5 to 10 feet wide. The top of the barrier should be at least 5 feet below the finished roadway.

- The brush barrier may be wrapped with an engineering fabric to improve filtering capacity, but this process is difficult and care must be taken to not rip the fabric. If a fabric is used, it should be trenched and compacted immediately uphill from the barrier then staked on the downhill side (see Figure 13).

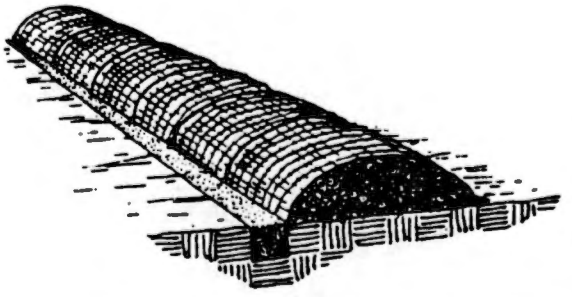
- If engineering fabric is not used, the barrier may be secured by tying it down using alternate stakes on each side of the barrier (see Figure 14).



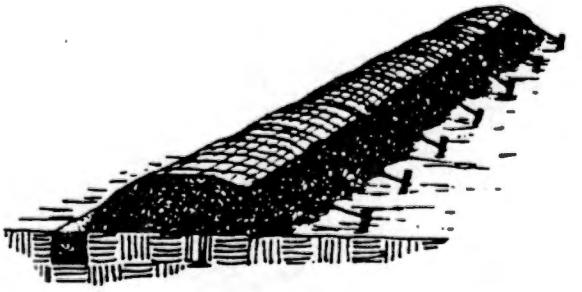
1. Excavate a 4" x 4" trench along the uphill edge of the brush barrier.



2. Drape filter fabric over the brush barrier and into the trench. Fabric should be secured in the trench with stakes set approximately 36" o.c.



3. Backfill and compact the excavated soil.



4. Set stakes along the downhill edge of the brush barrier, and anchor by tying twine from the fabric to the stakes.

Figure 13. Construction of a brush barrier covered by filter fabric.

Source: Virginia Soil and Water Conservation Commission, Virginia Soil and Erosion Control Handbook, Second Edition. Virginia Soil and Water Conservation Commission, Richmond, Virginia (1980).

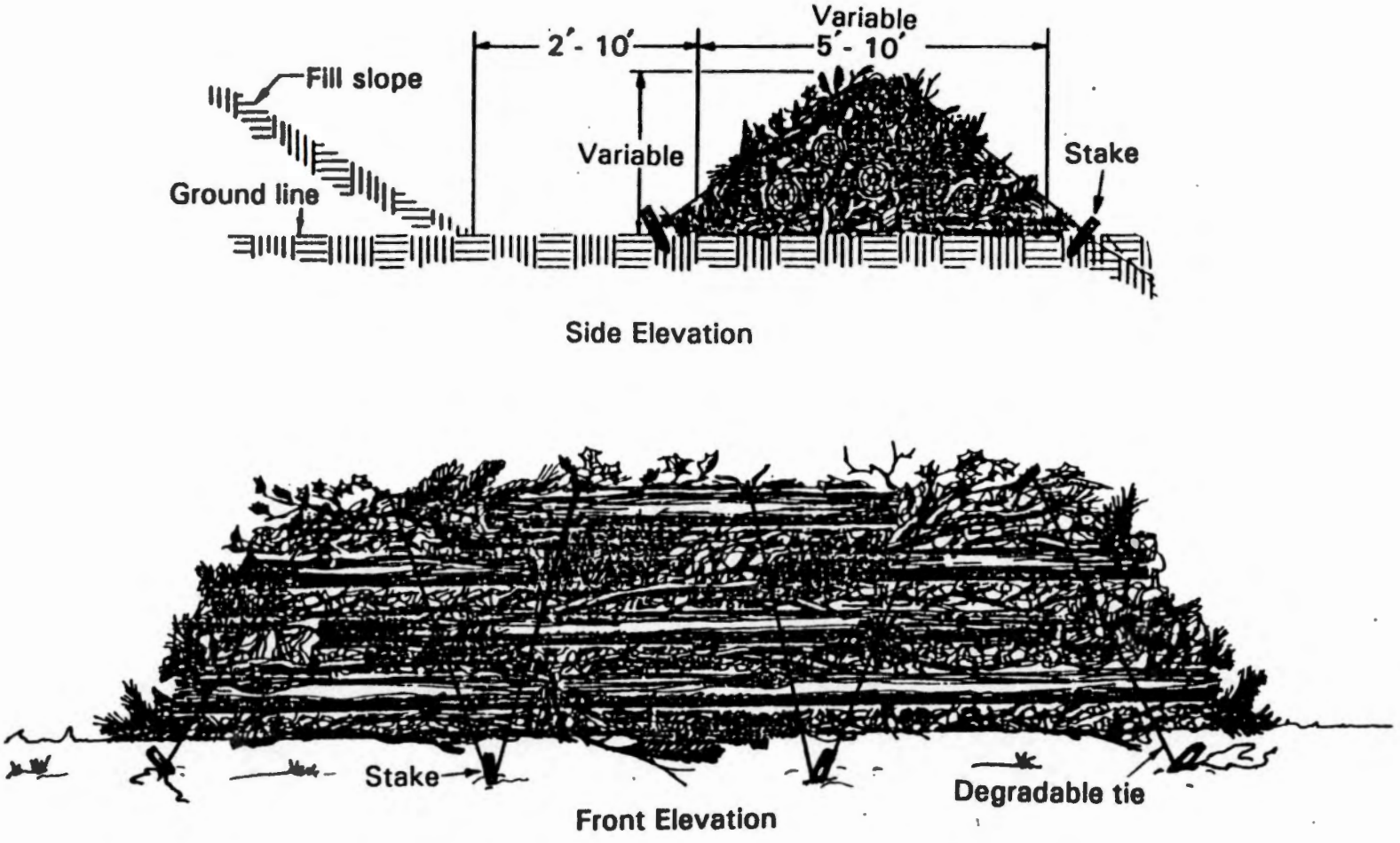


Figure 14. Standard brush barrier without filter fabric.

- A brush barrier may be left in place after construction unless it is in an aesthetically sensitive area or it is indicated otherwise on plans.

- A brush barrier can be used as a last resort if other controls are not currently available.

COMMON TROUBLE POINTS AND SOME CORRECTIVE MEASURES

- Once in place, difficult to repair.

- Difficult to remove; must be removed in aesthetically sensitive areas.

- Not enough brush; only brush within the construction limits should be used.

MAINTENANCE

Inspect a brush barrier after each rainfall and make necessary repairs. Sediment deposits should be removed when they reach approximately half the barrier's height.

REFERENCES

Connecticut Department of Transportation, 1986; Tennessee Department of Transportation, 1981; and Virginia Soil and Water Conservation Commission, 1980.

SECTION IV

WATER CONVEYANCE

DIVERSIONS

DESCRIPTION

A diversion is a berm (dike or ridge) and/or swale (excavated channel or ditch) used to prevent sediment-laden waters from leaving a site and to prevent off-site or upstream waters from entering a site. Typical diversions are combination berm/swale and may be temporary or permanent structures.

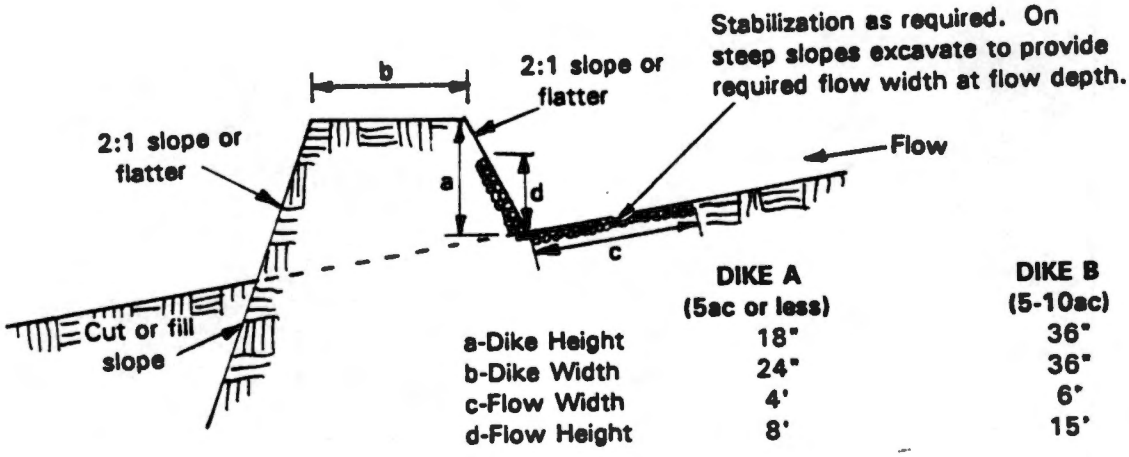
WHERE DIVERSIONS ARE USED

- At the toe of cuts or fills to direct sediment-laden runoff to sediment traps.
- At the top of cuts or around disturbed areas to divert clean runoff until the disturbed areas are permanently stabilized.
- At the top of steep slopes where excess runoff would cause erosion problems.
- At selected intervals on long, sloping routes to prevent erosion.
- Around a site to prevent entry of off-site runoff and to reduce flooding.

BASIC DESIGN AND CONSTRUCTION GUIDELINES

- Diversions should be designed to handle the peak runoff from a 10-year storm.
- Berms should be constructed of compacted soil, should have a minimum top width of 2 feet, should have a minimum height of 1 foot (with or without a swale), and should allow for 10 percent settlement. An earthen dike guideline is shown in Figure 15. Swale guidelines are listed in Figure 16. These may be used individually or in combination (see Figure 17). Side slopes should not exceed a 2:1 ratio.

Cross Section



	DIKE A (5ac or less)	DIKE B (5-10ac)
a-Dike Height	18"	36"
b-Dike Width	24"	36"
c-Flow Width	4'	6'
d-Flow Height	8'	15'

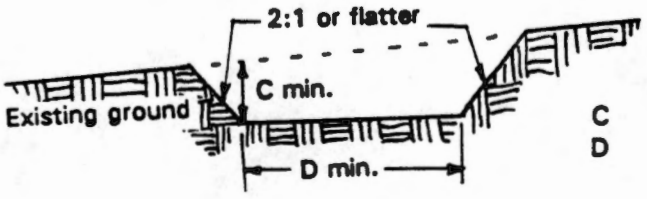
Flow Channel Stabilization

Channel Grade	DIKE A (5ac or less)	DIKE B (5-10ac)
.5-3.0%	seed and straw mulch	seed and straw mulch
3.1-5.0%	seed and straw mulch	stabilization matting, or sod
5.1-8.0%	seed with soil stabilization matting or sod	lined riprap (4-8")
8.1-20%	lined riprap (4-8")	engineering design

Figure 15. Earth dike guidelines.

Source: Maryland Department of Transportation, Erosion and Sediment Control. Maryland Department of Transportation State Highway Administration in cooperation with the Water Resources Administration, Baltimore, Maryland (1989, revised).

Cross Section



	Swale A	Swale B
C	1'	1'
D	4'	6'

Flow Channel Stabilization

Channel Grade	DIKE A (5ac or less)	DIKE B (5-10ac)
.5-5.0%	seed with soil stabilization matting	seed used with stabilization matting
5.1-8.0%	seed with soil stabilization matting	lined riprap (4-8")
8.1-20%	lined riprap (4-8")	engineering design

Figure 16. Temporary swale guidelines.

Source: Maryland Department of Transportation, Erosion and Sediment Control. Maryland Department of Transportation State Highway Administration in cooperation with the Water Resources Administration, Baltimore, Maryland (1989, revised).

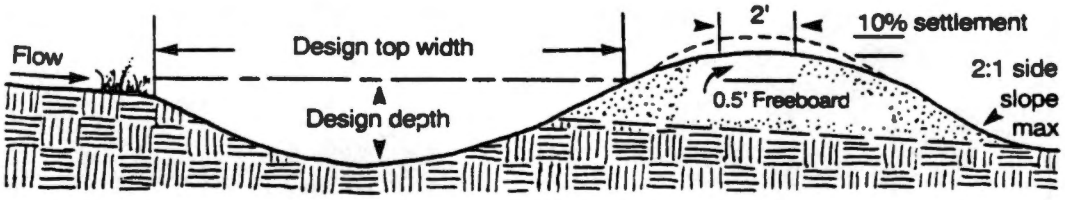


Figure 17. Combination dike and swale.

Source: North Carolina Sedimentation Control Commission, North Carolina Department of Natural Resources and Community Development, and North Carolina Agricultural Extension Service, Erosion and Sediment Control Planning and Design Manual. State of North Carolina Department of Natural Resources and Community Development, Raleigh, North Carolina (1988).

- When equipment crossing is necessary, diversions may be wider with flatter side slopes and/or lined with gravel to minimize erosion.

- When practical, minimize temporary diversions needed by constructing embankment ridges to slope to one side.

- Maximum grade is dependent on permissible velocity. Permissible velocity for vegetative stabilized diversions should not exceed values listed in Table 1.

- Outlets should be stabilized to prevent erosion and convey runoff to a point where it will not cause damage. Note the "Temporary Slope Drain" subsection of this section for design suggestions.

- Vegetate diversion immediately after construction unless the diversion will be in place fewer than 30 working days.

COMMON TROUBLE POINTS AND SOME CORRECTIVE MEASURES

- Berm is not properly compacted; an improperly compacted berm could fail in a heavy storm.

- Excessive grade; a steep grade requires protective liner or realignment to reduce grade.

- Sedimentation; sedimentation where channel grade decreases or changes course may cause overtopping. Realign or deepen channel to maintain grade.

- Low point in berm where diversion crosses a natural depression; build up berm.

- Vehicle crossing point; maintain berm height, flatten side slopes, and protect ridge with gravel at crossing point.

- Excessive velocity at outlet; install stabilization measures such as riprap or geotextile linings.

Table 1. Permissible velocities for diversions.

	Permissible Velocity — ft/sec (m/sec)			
	Channel Vegetation			
Soil Texture	Bare	Poor	Fair	Good
Sand, silt, sandy loam, and silty loam	1.5 (0.46)	1.5 (0.46)	2.0 (0.61)	3.0 (0.91)
Silty clay, loam and sandy clay loam	2.0 (0.61)	2.5 (0.76)	3.0 (0.91)	4.0 (1.22)
Clay	2.5 (0.76)	3.0 (0.91)	4.0 (1.22)	5.0 (1.52)

Source: Maryland Department of Transportation, Erosion and Sediment Control. Maryland Department of Transportation State Highway Administration in cooperation with the Water Resources Administration, Baltimore, Maryland (1989, revised).

MAINTENANCE

Permanent diversions should be checked following each rainfall until disturbed areas are stabilized. Inspect temporary diversions once a week and following each major rainfall event. Remove accumulated sediment from the channel. Check the dike, swale, and outlets and make necessary repairs immediately. Reseed areas that fail to establish a vegetative cover. Temporary diversions may be removed and blended with the natural topography when the area protected is permanently stabilized.

REFERENCES

North Carolina Sedimentation Control Commission et al., 1988; Oklahoma County Conservation District et al., 1988; Tennessee Department of Transportation, 1981; and Virginia Soil and Water Conservation Commission, 1980.

TEMPORARY SLOPE DRAIN

DESCRIPTION

A temporary slope drain is a structure used to convey water down the face of a cut or fill without causing erosion.

WHERE TEMPORARY SLOPE DRAINS ARE USED

Temporary slope drains are used in conjunction with berms along the edges of newly constructed slopes to prevent erosion. They are used along cut and fill slopes until permanent storm water drainage structures are installed.

BASIC DESIGN AND CONSTRUCTION GUIDELINES

Plastic lining; fiber matting; wooden flumes; metal, rigid, or flexible plastic pipe; and half round pipe are commonly used (see Figure 18). When plastic lining is used, a smooth, uniform ditch should be provided to prevent water from overflowing the sides. Fiber matting and plastic sheeting should not be used on slopes steeper than 4:1 except for short distances of 20 feet or less.

The base for temporary slope drains should be compacted and concavely formed to channel the water or to hold the slope drain in place. Inlets should be properly constructed to channel water into the drain (see Figure 19), and the drains anchored to withstand the force of the water. Anchoring can be accomplished by staking at approximately 10 foot intervals or by weighing down the drains with items such as riprap, sandbags, or compacted soil. Outlets should be constructed to reduce erosion downstream with items such as dumped rock, small sediment basins, or other approved devices.

Temporary slope drains should be installed at frequent intervals along continuous unprotected slopes and at low points in the roadway profile grade. Each slope drain should not exceed 5 acres of drainage area. Pipe connections should be watertight and secure so joints will not

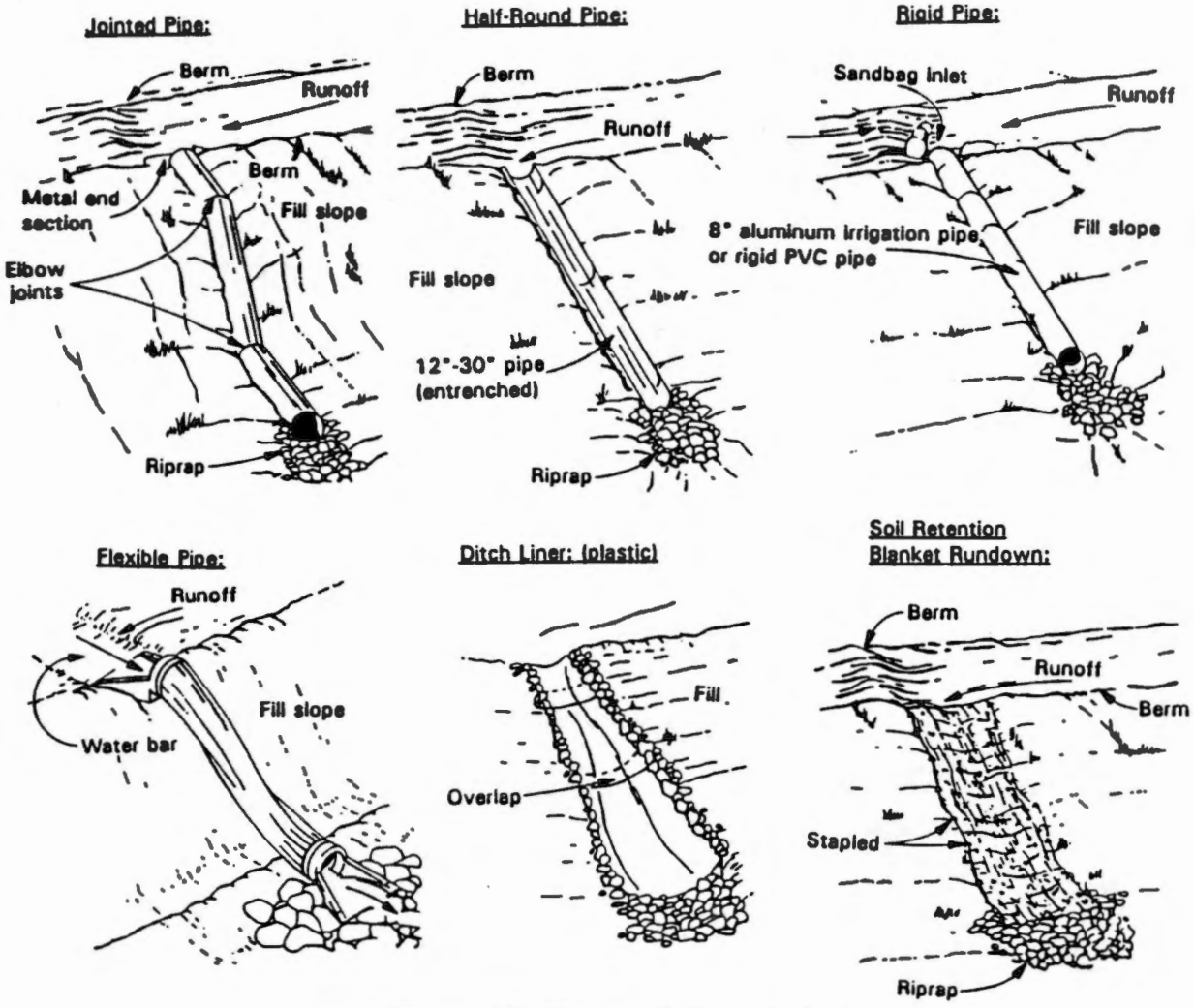


Figure 18. Types of slope drains

Source: Wyoming State Highway Department, Standard Plan for Temporary Soil Erosion Control Measures (1986).

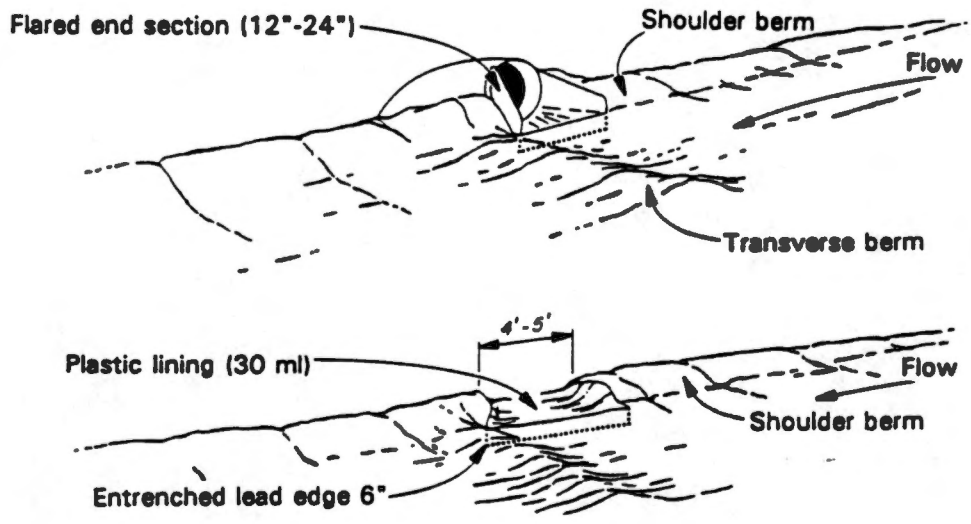


Figure 19. Examples of slope drain inlets.

Source: Wyoming State Highway Department, Standard Plan for Temporary Soil Erosion Control Measures (1986).

separate. Pipe diameters should be calculated by a qualified engineer, but a general guide is:

Minimum Pipe Diameter (in)	Maximum Drainage Area (acres)
12	0.5
15	0.75
18	1.5
21	2.5
24	3.5
30	5.0

COMMON TROUBLE POINTS AND SOME CORRECTIVE MEASURES

- Washout along the pipe/matting/flume due to seepage, piping, and/or overflow; a washout may occur because of inadequate compaction, insufficient fill, installation of drain too close to edge of slope, too steep a slope (open drains), too large a drainage area, or undersized conveyance channel.

- Overtopping of diversion caused by undersized or blocked pipe; drainage area may be too large.

- Overtopping of diversion caused by improper grade of channel and ridge; maintain positive grade.

- Erosion at outlet; pipe may not extended to stable grade or outlet stabilization structure may be needed.

- Displacement or separation of slope drain; the drain has inaccurate or insufficient anchorage.

MAINTENANCE

Inspect temporary slope drains weekly and following rainfall events. Some critical points that should be checked at each inspection are as follows.

- Check inlet and outlet for sediment or trash accumulation; clear and restore to proper condition.

- Check fill over pipe for settlement, cracking, or piping holes (seepage holes where pipe emerges from dike); problems should be repaired promptly.

- Check conduits for leaks or inadequate lateral support; problems should be repaired promptly.

REMOVAL

All temporary slope drains should be removed when no longer necessary and the site should be restored to match the surroundings.

REFERENCES

Colorado Department of Highways, 1978; Goldman et al., 1986; North Carolina Sedimentation Control Commission et al., 1988; and Tennessee Department of Transportation, 1981.

CHECK DAM

DESCRIPTION

A check dam is a small dam constructed in a drainageway to reduce channel erosion by reducing the flow velocity.

WHERE CHECK DAMS ARE USED

- Check dams are appropriate for use in small drainage ditches and are **not for use in perennial streams.**
- In temporary swales and ditches where lining with nonerodible materials is not practical but erosion protection is necessary.
- Used when construction delays or weather conditions prevent timely installation of nonerodible lining.
- Used in temporary or permanent ditches or swales which need protection during the establishment of grass linings.

BASIC DESIGN AND CONSTRUCTION GUIDELINES

- Check dams are usually constructed of riprap, logs, sandbags, and/or straw bales. Although check dams are sometimes used as sediment traps, their primary purpose is to slow down water velocity along the drainage path which helps reduce shear and, thus, erosion.
- The maximum check dam height should be 2 feet.
- Multiple check dams should be spaced so that the bottom elevation of the upper dam is the same as the top elevation of the next dam downstream, as illustrated in Figure 20.
- The center of the check dam should be a minimum of 6 inches lower than the ends to act as a spillway for runoff, as shown in Figure 20.

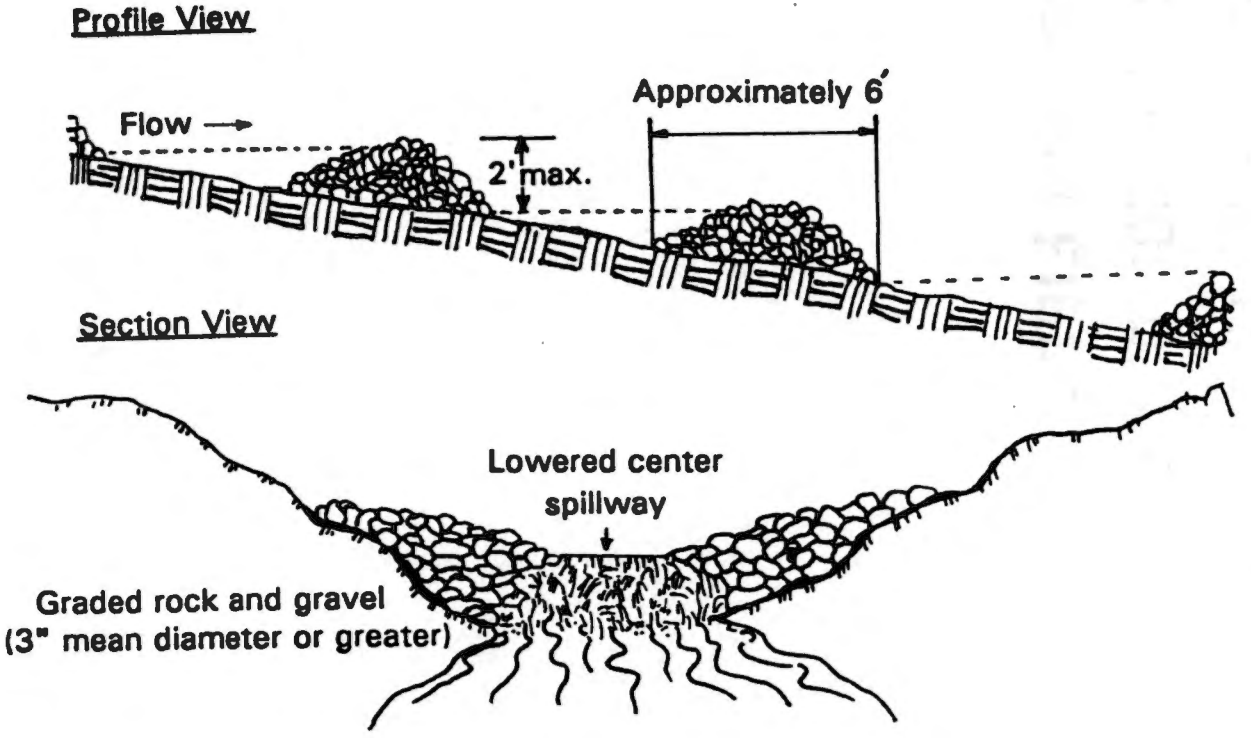


Figure 20. Basic design of rock check dams.

- Overflow areas should be stabilized to resist erosion.

- Stone check dams should use 3 inch or larger stone with side slopes of 2:1 or flatter and should be keyed into the sides and bottom of the channel a minimum depth of 2 feet. The drainage area for a stone check dam meeting these design criterias should not exceed 50 acres.

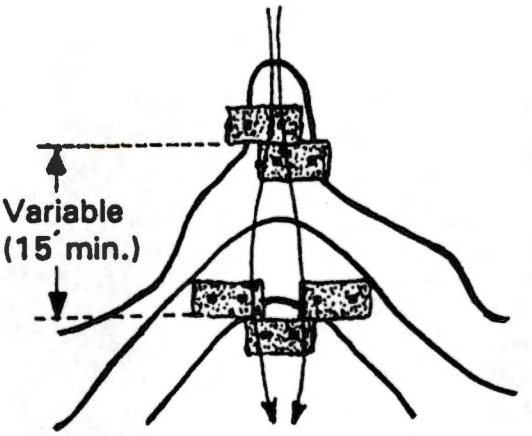
- Log dams should be constructed with 4 to 6 inch diameter logs and embedded a minimum of 2 feet. The drainage area for a log check dam should not exceed 5 acres. Note that removal of a log check dam can result in more soil disturbance than removal of other types of check dam, therefore, log check dams are desirable when to be left in place.

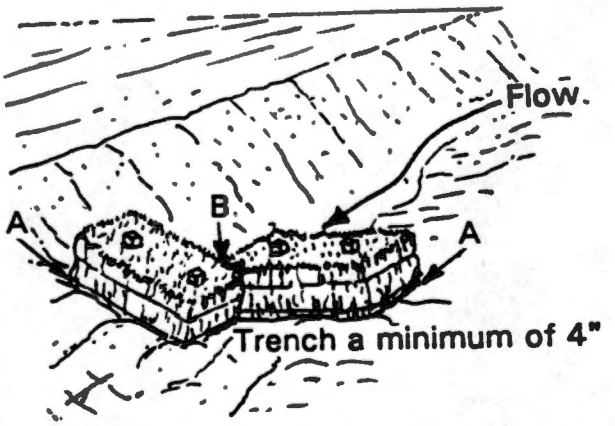
- Straw bales are effective with low flows and should be overlapped and embedded a minimum of 4 inches with stakes angled slightly upstream (see Figure 21). The drainage area for straw check dams should not exceed 2 acres.

- Burlap bags filled with soil and bermudagrass roots are also effective check dams. This may be desirable in ditches and small gullies when solid sodding cannot be done. One pound of 6-12-12 fertilizer or equivalent should be mixed with each bag. Place bags 10 to 20 feet apart, ensure bags cover the entire flow area (similar to Figure 21 illustration) and are staked to prevent displacement. A handful of nitrogen fertilizer scattered on each bag when grass starts growth hastens establishment of complete ground cover.

COMMON TROUBLE POINTS AND SOME CORRECTIVE MEASURES

- Sedimentation; check dams are designed for velocity reduction and erosion control and are not intended to trap sediment, although sediment buildup will often occur. Sedimentation can clog the dam causing ponding which may kill the vegetative lining if submergence after rains is too long and/or siltation is excessive.





Point A should be higher than point B

Figure 21. Typical straw/hay check dam.

- Overflow area not stabilized, resulting in downstream erosion; stabilize the streambed and bank with riprap or equivalent. Extension of downstream embankments to stable grades is also effective.

- Overflow occurs at the abutments; lower or enlarge the spillway, or extend endpoints to a higher elevation.

MAINTENANCE

Regularly inspect a check dam to ensure the dam has not been breached or otherwise damaged from recent stream flow. The center elevation of the dam should be checked to ensure it is lower than the ends of the dam. Sediment accumulation behind the dam should be removed as determined by the project manager to prevent damage to channel vegetation and to allow the channel to drain through the dam; otherwise sediment should be removed when it reaches half the dam's height. Repair a damaged check dam promptly so the check dam will be fully functional for the next runoff event.

REMOVAL

Check dams may be removed when their useful life has been completed. All stones should be removed from grass channels that require mowing. Care should be taken when removing check dams so as not to damage channels that are permanent.

REFERENCES

Maryland Department of Transportation et al., 1989; North Carolina Sedimentation Control Commission et al., 1988; Oklahoma County Conservation District et al., 1988; Tennessee Department of Transportation, 1981; Virginia Soil and Water Conservation Commission, 1980; and Wang and Grubbs, 1990.

OUTLET PROTECTION

DESCRIPTION

Outlet protection involves the use of an energy dissipating device at the outlet of a pipe or conduit to prevent excessive erosion (scour) from the discharge of runoff.

WHERE OUTLET PROTECTION IS USED

Outlet protection is needed at outlets subjected to erosion and scour due to the exit velocity exceeding the allowable velocity for the soil discharged upon.

BASIC DESIGN AND INSTALLATION GUIDELINES

Concrete/Paved Outlet Protection

Concrete or paved outlet protection is a permanent form of structure and, therefore, should be designed by a qualified engineer. The design and installation of such a structure should follow plan specifications.

Riprap Outlet Protection

Refer to "Riprap" subsection of Section VI for guidance on sizing of riprap and filter stone.

Excavate subgrade below design elevation to allow for thickness of filter and riprap. Compact any fill used in the subgrade to the density of the surrounding undisturbed material. When applicable, smooth subgrade to prevent tear of filter fabric. Even if not shown on plans, filter stone, fabric, or a blanket should be placed prior to riprap installation to help prevent subgrade erosion. Filter fabrics should be of extra-strength quality and should be installed in continuous sections, placing the upstream section of fabric a minimum of 1 foot over the downstream section of fabric. Fabrics that are torn during riprap installation should be fully replaced.

Install riprap of the size and thickness as shown on plans to ensure a minimum thickness of 1.5 times the maximum stone diameter. Maintain final structure to the lines and elevations as shown in plans, taking care not to place stones above the finished grade. The outlet should blend with the surrounding topography.

Apron Installation

Nondefined Channel

Apron should be constructed on zero grade, aligned straight, and be long enough to adequately dissipate energy. There should be no restrictions or overfall from the apron end to the receiving grade. Figure 22 illustrates the basic outlet design for a nondefined channel.

Well-Defined Channel

Apron should be straight and properly aligned with the receiving stream. The apron should extend to the top of the bank and be long enough to adequately dissipate energy. There should be no restrictions or overfall from the apron end to the receiving channel. Figure 23 illustrates the basic outlet design for a well-defined channel.

COMMON TROUBLE POINTS AND SOME CORRECTIVE MEASURES

- Foundation not excavated deep enough or wide enough; riprap restricts flow across section, resulting in erosion around apron and scour holes at outlet.

- Riprap apron not on zero grade; this may cause erosion downstream.

- Stones too small or not properly graded; this results in movement of stone and downstream erosion.

- Riprap not extended far enough to reach a stable section of channel or to adequately dissipate energy; this results in downstream erosion.

- Appropriate filter not installed under riprap; this may result in stone displacement and erosion of foundation.

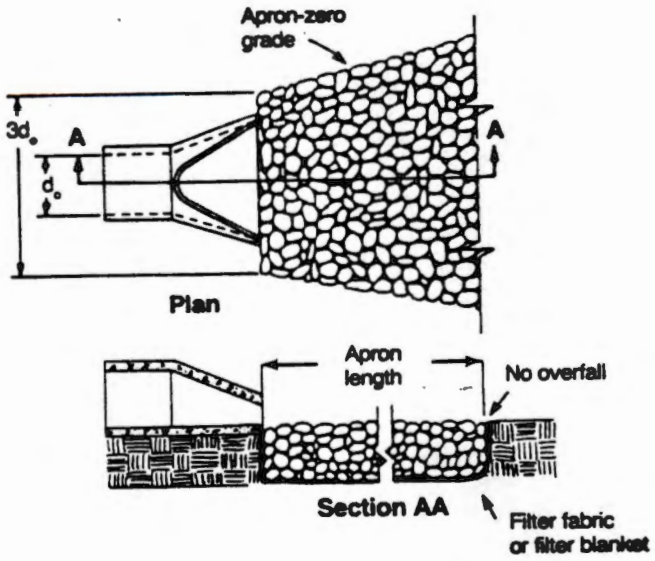


Figure 22. Pipe outlet to flat area with no well-defined channel.

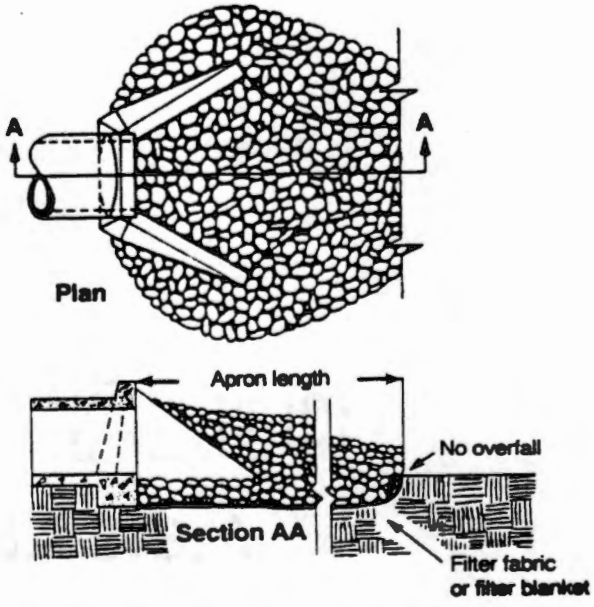


Figure 23. Pipe outlet to well-defined channel.

Source: North Carolina Sedimentation Control Commission, North Carolina Department of Natural Resources and Community Development, and North Carolina Agricultural Extension Service, Erosion and Sediment Control Planning and Design Manual. State of North Carolina Department of Natural Resources and Community Development, Raleigh, North Carolina (1988).

MAINTENANCE

Riprap outlet structures do not require much maintenance when properly installed, but they should be checked after significant rainfall events for erosion at sides and ends of the apron and for stone displacement. Repair damage immediately using appropriate stone sizes.

Riprap outlet structures should be checked periodically during growing seasons to ensure the flow is not being restricted due to vegetation establishment on the structure. Clearing vegetation during early stages of growth will help keep long term labor cost at a minimum.

REFERENCES

North Carolina Sedimentation Control Commission et al., 1988; and Oklahoma County Conservation District et al., 1988.

INLET PROTECTION

DESCRIPTION

Inlet protection involves using a temporary barrier to prevent the inflow of settleable sediments and debris into a storm drain or other form of conduit.

WHERE INLET PROTECTION IS USED

Inlet protection is used to prevent sediment from entering and clogging the storm drainage system prior to permanent stabilization of a construction area. This practice helps to keep the conveyance channel free from debris or sedimentation that could reduce the capacity of the channel.

BASIC DESIGN AND INSTALLATION GUIDELINES

Several techniques of inlet protection currently exist. Each procedure may require excavation and/or the use of a dike or berm (illustrated in Figures 24 through 26) for establishment of a drop area. When used, a berm should be so placed to restrict flow bypass and allow for ponding at the inlet in order that the suspended sediment may settle out. The berm should be constructed slightly higher (2 to 3 inches at minimum but 6 inches recommended, see Figure 24) than the top of the inlet. A trash rack may be necessary to prevent clogging of the inlet.

Drop areas are used to promote ponding that allows for settlement of sediment and to help prevent flow bypass of the inlet. Although other innovative techniques exist for accomplishing the same purpose, basic design and installation procedures for some of the most commonly applied processes are as follows:

Excavated Drop Inlet Protection

This process is limited to maximum drainage areas of 1 acre. The area is excavated 1 to 2 feet deep and wide enough to create a total storage volume of at least 35 cubic yards per acre. When possible,

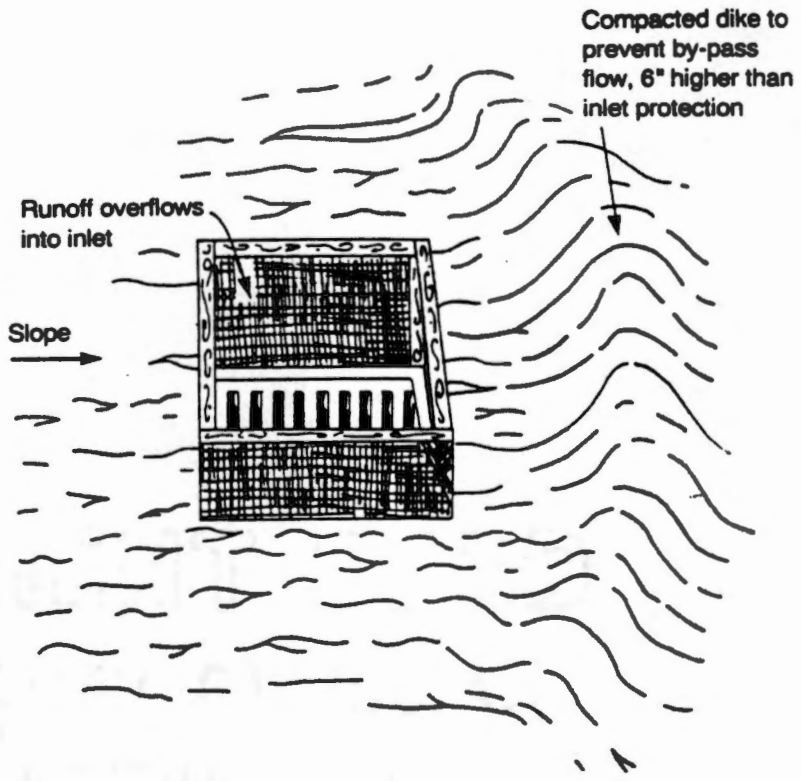


Figure 24. Prevent bypass flow with a dike on the downslope side.

Source: North Carolina Sedimentation Control Commission, North Carolina Department of Natural Resources and Community Development, and North Carolina Agricultural Extension Service, Erosion and Sediment Control Planning and Design Manual. State of North Carolina Department of Natural Resources and Community Development, Raleigh, North Carolina (1988).

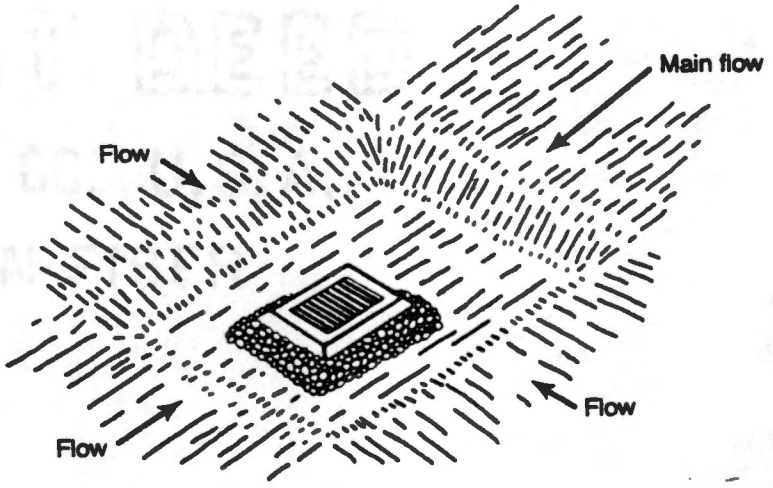


Figure 25. Perspective of excavated drop inlet protection.

Source: North Carolina Sedimentation Control Commission, North Carolina Department of Natural Resources and Community Development, and North Carolina Agricultural Extension Service, Erosion and Sediment Control Planning and Design Manual. State of North Carolina Department of Natural Resources and Community Development, Raleigh, North Carolina (1988).

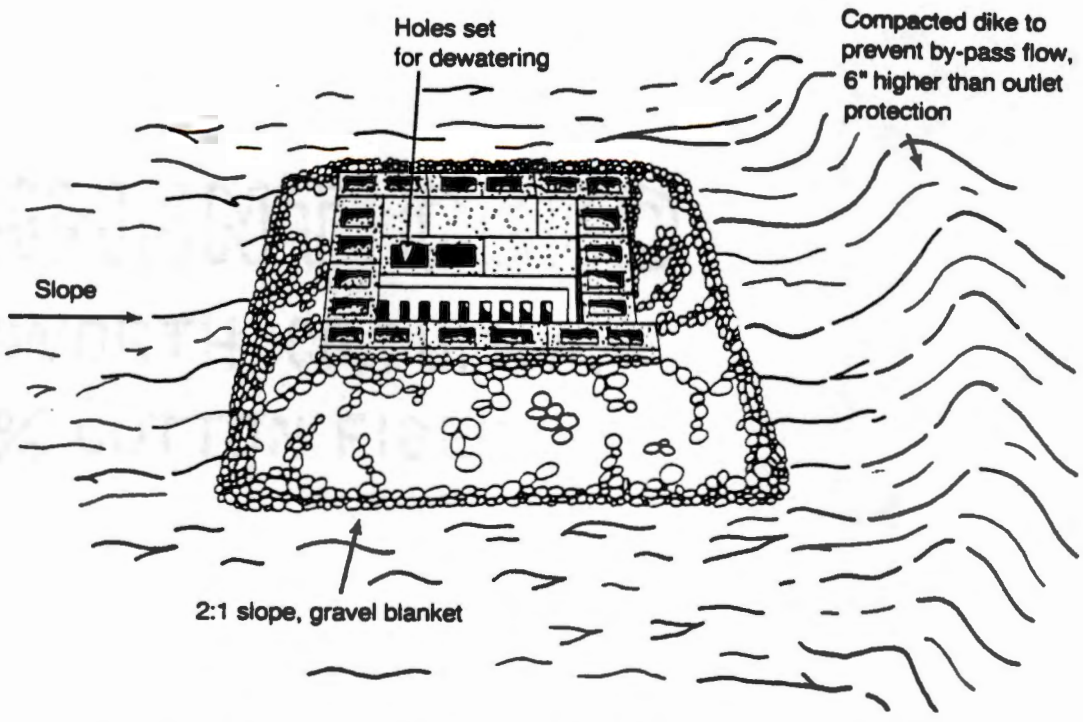


Figure 26. Perspective of block and gravel drop inlet protection.

Source: North Carolina Sedimentation Control Commission, North Carolina Department of Natural Resources and Community Development, and North Carolina Agricultural Extension Service, Erosion and Sediment Control Planning and Design Manual. State of North Carolina Department of Natural Resources and Community Development, Raleigh, North Carolina (1988).

shape the basin to orient the longest dimension toward the largest inflow, as illustrated in Figure 25. Side slopes should be 2:1 or flatter.

Common inlet protection techniques for this method include placement of weep holes at the bottom of the basin to allow drainage of the trap, covering of weep holes with a wire mesh or hardware cloth, then covering with gravel to hold sediment in place (see Figure 27). It is important that the openings in the mesh be slightly less than the minimum size aggregate used to prevent gravel from entering the inlet. A maximum 1 inch gravel size is suggested.

Excluding the basin, stabilize the surrounding area as shown on plans.

Straw Bale Drop Inlet Protection

This process is limited to maximum drainage areas of 1 acre. The straw bales should meet the requirements for a Straw Bale Barrier (see Section III). Bales are placed in a 4 to 6 inch trench dug around the inlet and are staked in accordance to the requirements for a Straw Bale Barrier. Note Figures 28 and 29 for illustrated examples. Bales can be anchored in areas where trenching is not feasible, such as a finished road surface, by placing gravel around the base of the bales. Tightly chinking spacings between bales with loose straw is suggested to prevent sediment-laden runoff from free flow.

Filter Fabric Inlet Protection

This process is limited to maximum drainage areas of 1 acre. The fabric should be of extra-strength quality and resistant to ultraviolet degradation if duration of use will exceed 60 days. A wire fence (14 gauge minimum with a maximum mesh spacing of 6 inches) may be necessary to support the fabric.

Support posts should be either steel fence posts or 2 x 4 inch wooden post, each at least 3 feet long. The structure should be able to support a 1.5 foot head of water and sediment without collapsing or undercutting. Posts should be driven approximately 1.5 feet and include, when necessary, top supports to prevent collapse of the structure as shown in Figure 30.

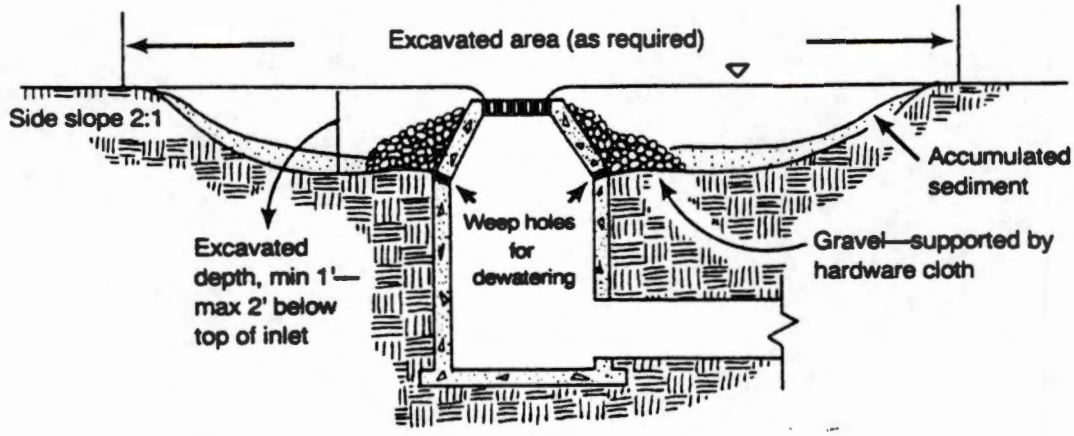


Figure 27. Cross section of excavated drop inlet protection.

Source: North Carolina Sedimentation Control Commission, North Carolina Department of Natural Resources and Community Development, and North Carolina Agricultural Extension Service, Erosion and Sediment Control Planning and Design Manual. State of North Carolina Department of Natural Resources and Community Development, Raleigh, North Carolina (1988).

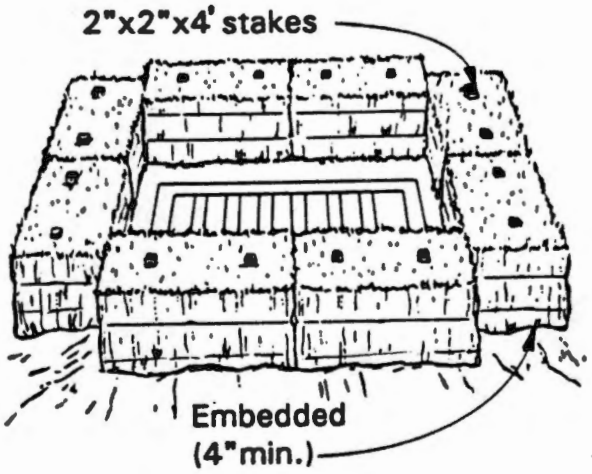


Figure 28. Straw/hay bale inlet protection.

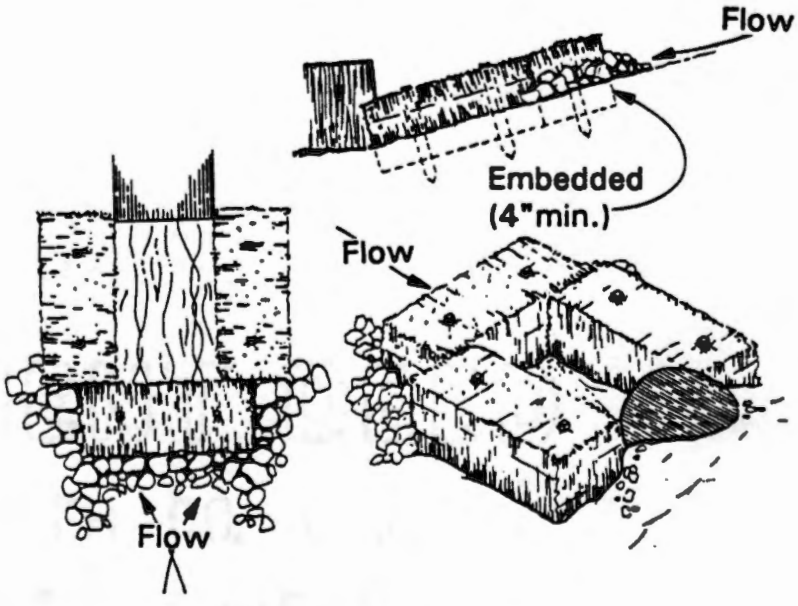


Figure 29. Straw/hay bale culvert inlet protection.

Source: Wyoming State Highway Department, Standard Plan for Temporary Soil Erosion Control Measures (1986).

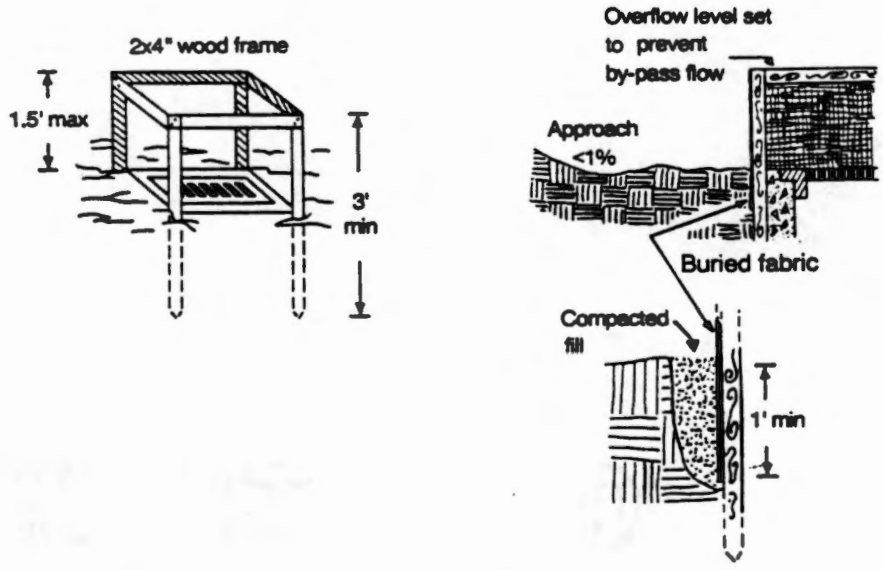


Figure 30. Recommended installation of fabric with supporting frame around stormwater inlet.

Source: North Carolina Sedimentation Control Commission, North Carolina Department of Natural Resources and Community Development, and North Carolina Agricultural Extension Service, Erosion and Sediment Control Planning and Design Manual. State of North Carolina Department of Natural Resources and Community Development, Raleigh, North Carolina (1988).

Fabric should be a continuous sheet, trenched at least 1 foot to prevent undercutting, then backfilled and compacted with soil or crushed stone. Secure fabric to the post and/or support fence (when used), stretching fence to top level (see Figure 24). The top should be level to help provide for uniform overflow.

Gravel and Wire Mesh Drop Inlet Protection

This process is limited to maximum drainage areas of 1 acre. A wire mesh or hardware cloth is laid directly over the drain, overlapping a minimum of 1 foot in each direction from the drain. Approximately 1 foot of gravel is then placed directly over the mesh. It is important that the openings in the mesh be slightly less than the minimum size aggregate used to prevent gravel from entering the inlet. A maximum 1 inch gravel size is suggested. Place gravel so a small gap is left open around the top of the inlet to allow for relief during a flood.

Block, Gravel, and Wire Mesh Drop Inlet Protection

If large amounts of sediment are expected, blocks may be stacked around the inlet to temporarily elevate it. The bottom row of blocks are placed with holes horizontal, covered with wire mesh or hardware cloth, then covered with gravel to allow for dewatering (see Figure 25). The height of such structures should not exceed 2 feet. The top of the gravel should be placed at lease 2 to 4 inches below the top of the block structure to prevent gravel from washing into the drain. Gravel side slopes should be 2:1 or flatter (see Figure 31).

COMMON TROUBLE POINTS AND SOME CORRECTIVE MEASURES

- Sediment fills the designated trap and enters the storm drain; the sediment-producing area is too large for installed trap or the inlet is not properly maintained and cleaned.

- Excessive ponding around inlet; the gravel or other appropriate dewatering method may be clogged with sediment. Remove debris, clear sediment, and replace dewatering device being used.

- Sediment not removed from trap; failure to remove sediment may result in inadequate storage volume for next storm.

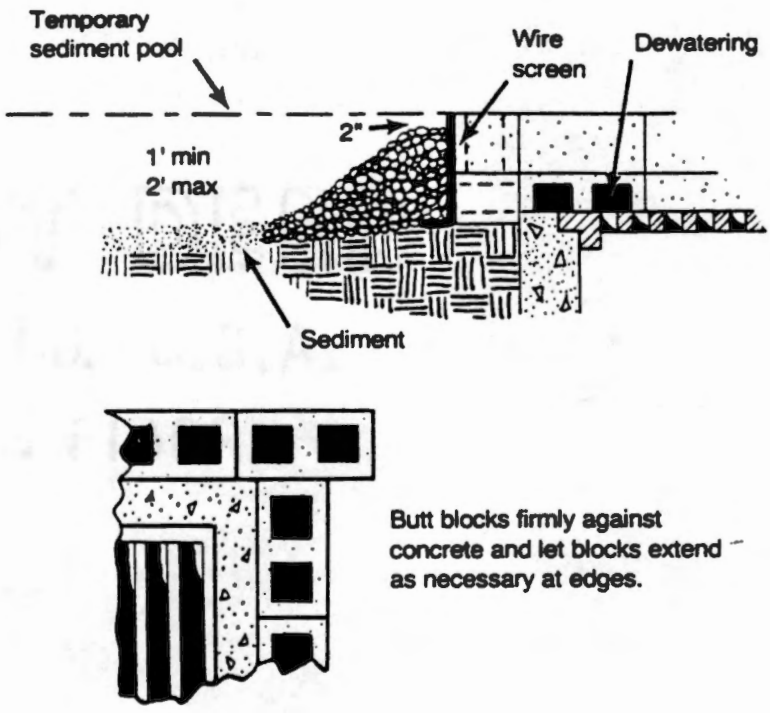


Figure 31. Detail of block and gravel block drop inlet.

Source: North Carolina Sedimentation Control Commission, North Carolina Department of Natural Resources and Community Development, and North Carolina Agricultural Extension Service, Erosion and Sediment Control Planning and Design Manual. State of North Carolina Department of Natural Resources and Community Development, Raleigh, North Carolina (1988).

- Protection device not erected against inlet; this may result in erosion and undercutting of the inlet.

- Temporary dike below the inlet not maintained; this may result in flow bypassing the inlet, thus inducing flow that could exceed design capacity of the downgradient storm inlet.

- Post and fabric not supported at top; this may result in collapse of the structure.

- Fabric not properly buried at bottom; this may result in undercutting.

- Fabric barrier constructed too high; this may result in stormwater bypassing the storm inlet or collapsing structure.

- Flooding and erosion due to blockage of inlet; install a trash guard.

MAINTENANCE

The effectiveness of the inlet protection is dependent on follow-up maintenance. Inspect inlets following each storm event and remove accumulated sediment and debris. Make any needed repairs immediately.

REMOVAL

When the contributing drainage area has been stabilized, inspected, and approved, remove construction materials and any unstable sediment from inlet and dispose of them properly. When necessary, grade the disturbed area to the inlet elevation as shown on plans. Stabilize all bare areas immediately.

REFERENCES

Goldman et al., 1986; and North Carolina Sedimentation Control Commission et al., 1988.

SECTION V

SEDIMENT DETENTION PONDS AND BASINS

TEMPORARY SEDIMENT TRAP

DESCRIPTION

A temporary sediment trap is a control device used to intercept sediment-laden runoff and to trap sediment to prevent/reduce off-site sedimentation. A temporary sediment trap can be formed by excavation and/or embankments constructed at designated locations accessible for cleanout. This procedure works by providing a pool which slows velocities and allows settlement of the suspended sediment.

WHERE TEMPORARY SEDIMENT TRAPS ARE USED

A temporary sediment trap may be located in a drainageway, at a storm drain inlet, or at other points of discharge from a disturbed area.

A temporary sediment trap may be constructed independently or in conjunction with diversions.

A temporary sediment trap may be used in most drainage situations to prevent excessive siltation of pipe structures.

BASIC DESIGN AND CONSTRUCTION GUIDELINES

A temporary sediment trap is used for drainage areas of 5 acres or less (refer to the "Sediment Basin" subsection of this section if the drainage area is larger) and has an expected life span of no more than 2 years.

Sizing the trap is generally dependent on the space available. When space is available, practice shows that 67 cubic yards per acre of drainage area produces acceptable trapping efficiency.

Sediment traps may not be very effective with settlement of fine silts and clays. Such materials require large holding areas to provide time necessary for gravimetric settlement. A sediment basin with a chemical flocculant additive (see "Sediment Basin" subsection of this

section for details) may prove more desirable when dealing with an area consisting of such material.

When an embankment is required it should not exceed 5 feet in height, the top width should be at least 5 feet, and side slopes should be 2:1 or flatter.

As a rule of thumb, the spillway should be at least 1.5 feet deep and a minimum of 4 feet wide. A spillway width to drainage area size guide is as follows:

Drainage Area (acres)	Minimum Bottom Width (ft)
1	4.0
2	6.0
3	8.0
4	10.0
5	12.0

A temporary sediment trap should not be located within 20 feet of a building foundation if the trap is to function during building construction.

All sediment structures should be twice as long as they are wide. Examples of sediment traps are illustrated in Figures 32 through 35.

COMMON TROUBLE POINTS AND SOME CORRECTIVE MEASURES

- Inadequate spillway size; this results in overtopping of dam, poor trap efficiency, and possible failure of the structure.

- Omission or improper installation of filter fabric (under riprap outlets); this results in washout under sides or bottom of the stone outlet section (piping).

- Low point in embankment caused by inadequate compaction and settling; this can result in overtopping and possible failure.

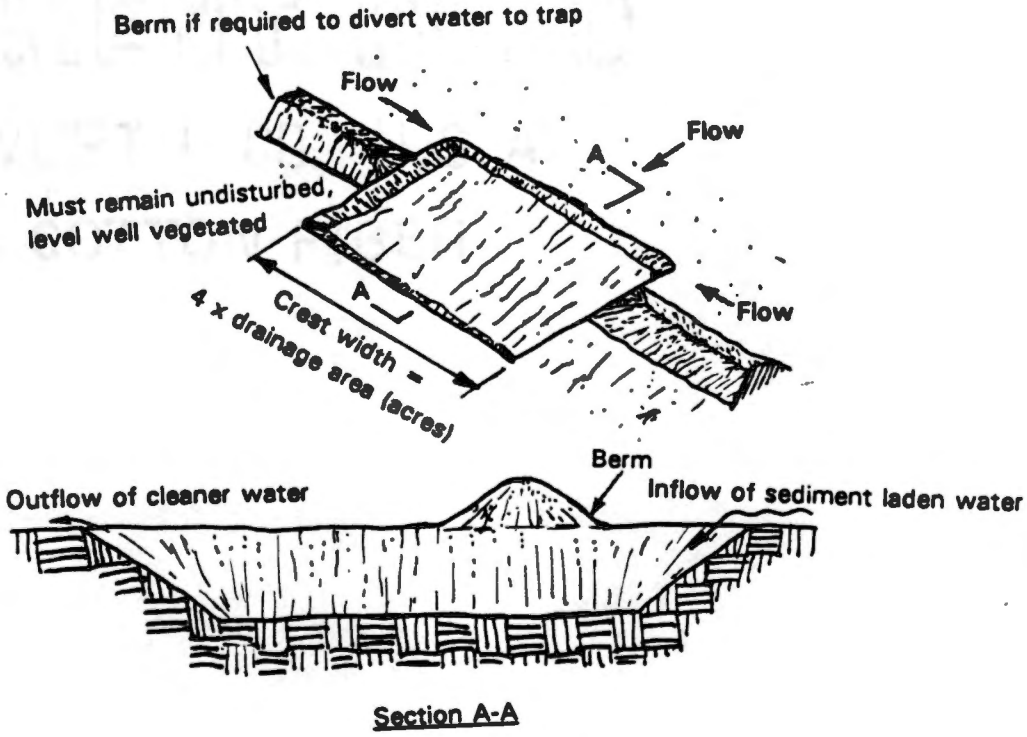


Figure 32. Excavated grass outlet sediment trap.

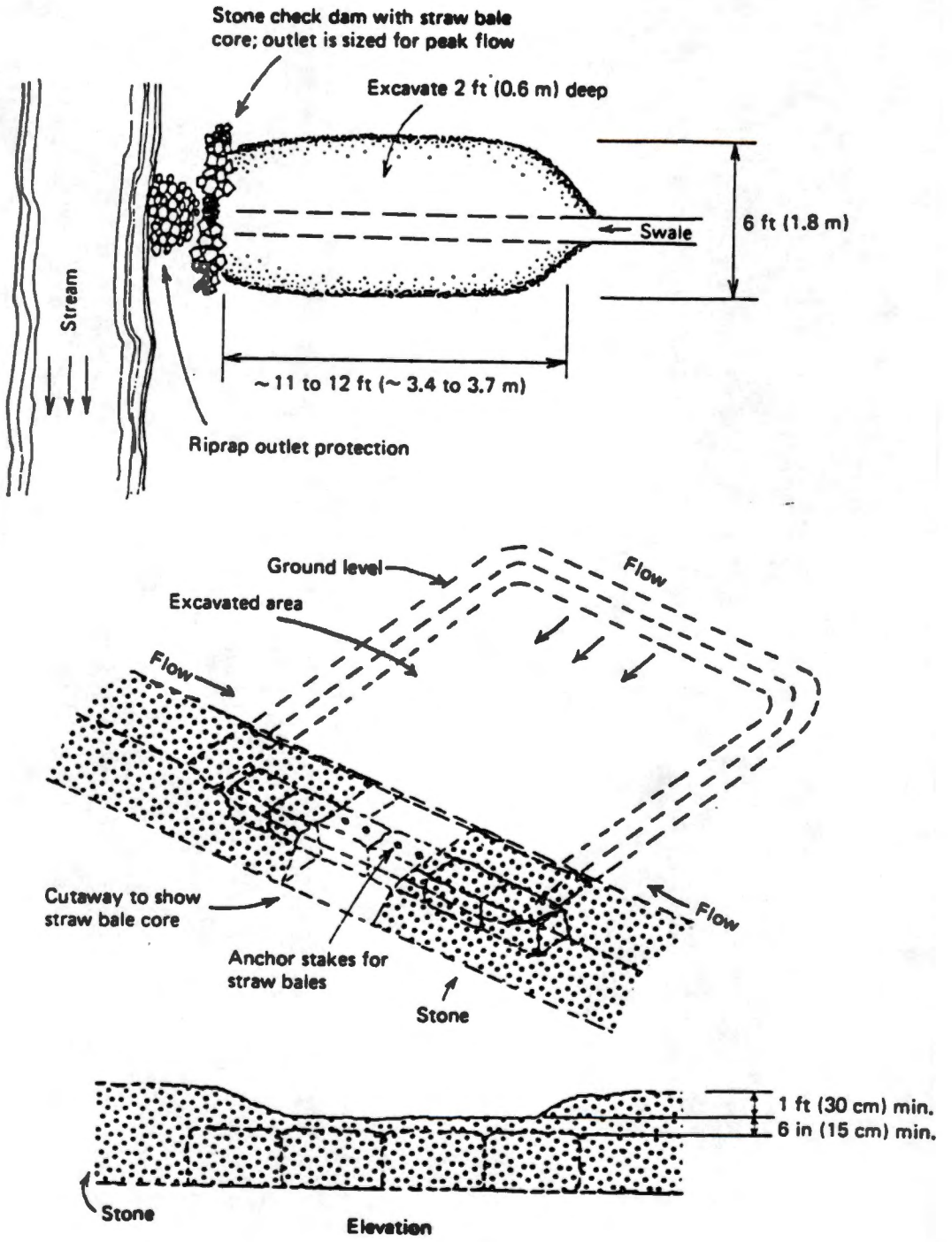
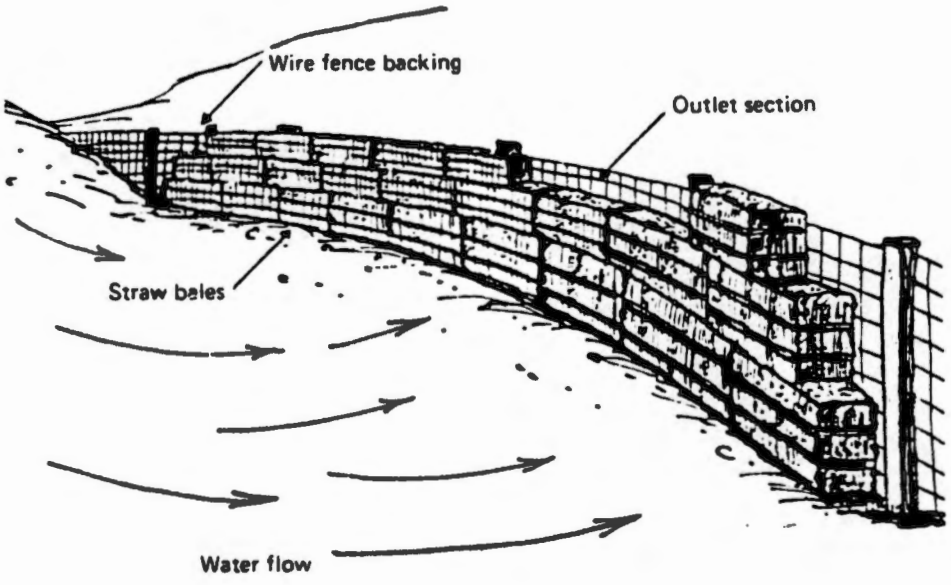


Figure 33. Stone dam with straw/hay bale core sediment trap.

Source: Goldman, S.J., Jackson, K., and Bursztynsky, T., Erosion and Sediment Control Handbook. McGraw-Hill Book Company, New York, New York (1986).



Note: Should not exceed maximum height of three bales.

Figure 34. Straw bale sediment trap.

Source: Goldman, S.J., Jackson, K., and Bursztynsky, T., Erosion and Sediment Control Handbook. McGraw-Hill Book Company, New York, New York (1986).

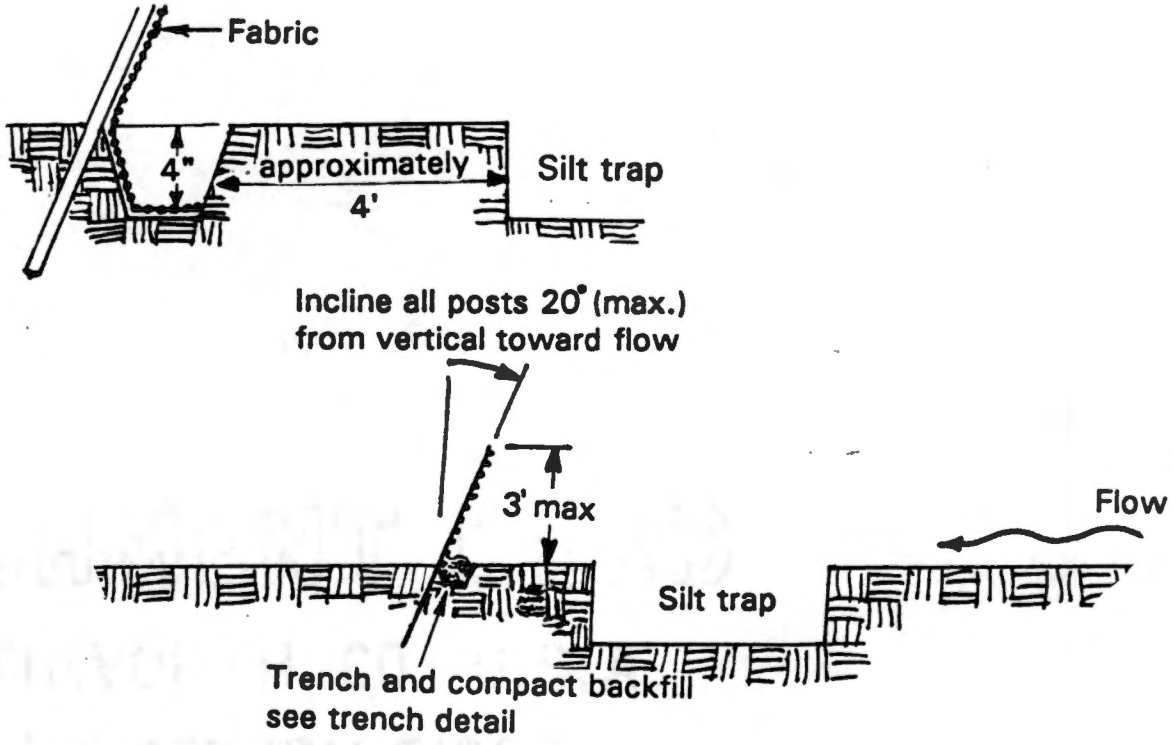


Figure 35. Details of fabric silt fence with silt trap.

- Outlet not extended to stable grade; this can result in erosion below the dam.

- Stone size too small or back slope too steep; this may result in stone displacement.

- Inadequate vegetative protection; this can result in erosion of embankment.

- Inadequate storage capacity; the sediment is not removed from basin frequently enough.

- Contact slope between stone spillway and earth embankment too steep; piping failure is likely.

- Improper maintenance; may cause poor trap efficiency or failure.

MAINTENANCE

Inspect temporary sediment traps following each significant rainfall event and repair any erosion and piping holes immediately. Trap should be cleaned out when sediment reaches one-half the design depth; a stake set at the cleanout level is helpful. Gravel facing should be cleaned or replaced if clogged. Check spillway depth periodically to ensure minimum 1.5 foot depth.

REMOVAL

Do not remove the sediment trap until all sediment producing areas have been permanently stabilized. The accumulated sediment in the trap should be removed, and all excavation should be backfilled and properly compacted. Smooth the site to blend with the terrain or as specified on plans.

REFERENCES

Colorado Department of Highways, 1978; North Carolina Sedimentation Control Commission et al., 1988; Oklahoma County Conservation District et al., 1988; Tennessee Department of Transportation, 1981; and Wang and Grubbs, 1990.

SEDIMENT BASIN

DESCRIPTION

A sediment basin is a stormwater detention structure formed by constructing a dam across drainageways or at other suitable locations and using it to intercept sediment-laden runoff. Sediment basins are generally larger and more effective in retaining sediment than temporary sediment traps. Dams that can store at least 30 acre-feet of runoff **or** are 20 feet or more in height must meet requirements established by the Tennessee Safe Dam Act and Requirements.

WHERE SEDIMENT BASINS ARE USED

Sediment basins should be located and designed such that failure of the structure would not result in loss of life; in damage to homes, commercial buildings, highways, and streets; or in interruption of the use of services or public utilities.

Regions that require post-development flow to be less than or equal to pre-development flow may employ the designed peak-flow reduction basin as a temporary sediment basin during construction.

BASIC DESIGN AND CONSTRUCTION GUIDELINES

1. The drainage area for a sediment basin should not exceed 100 acres.

2. Rule-of-thumb volume necessary for a sediment basin is about 1,800 cubic feet per acre of drainage area. This should provide a low maintenance working system that does not require clean out until half-filled with sediment.

3. Estimated volume available (V) in cubic feet is:

$$V = 0.4 \times \text{surface area (square feet)} \times \text{maximum depth (feet)}$$

where the maximum depth is taken from the lowest point in the spillway to the deepest portion of the pond (if the volume exceeds 30 acre-feet, note "Description" above).

4. Basic design for a sediment basin is illustrated in Figure 36. Embankment side slopes should be 2:1 or flatter with a minimum top width of 8 feet for dams less than 10 feet in height. Dams greater than 10 feet in height should have 2.5:1 or flatter slopes with a minimum top width of 10 feet. Side slopes of this design should provide appropriate embankment stability and a slope that is suitable for mowing equipment. Embankments should be keyed in with a minimum 2 foot x 2 foot trench. Embankment height should include a 10 percent settlement allowance and include a minimum 1 foot freeboard between the maximum water level and top of the dam.

5. Length to width ratio of the basin should be 2:1 or greater, with inflow located at the upper end of the basin or baffles used to avoid short-cutting and dead storage. Some baffle examples are illustrated in Figure 37.

6. The height of a dam is measured from the top to the lowest point at the downstream toe. (See "Description" above if dam exceeds this height.)

7. A chemical flocculent agent may be added to help promote settlement of fine silts and clays when such sediments are excessive, when sediments are occurring in areas sensitive to sedimentation, or when turbidity occurs downstream from the trap. Only nontoxic settling agents may be used. Chemicals are only effective in the tranquil water of a sediment trap but are often added upstream in turbulent waters to help with uniform mixing, as illustrated in Figure 38.

8. Sediment basins are usually only 70-80 percent effective in trapping sediments that flow into them and should thus be used in conjunction with the erosion control practices covered in this manual. The sediment removal percentage can be estimated for a given discharge and surface area ratio for the various soil characteristics by using Figure 39.

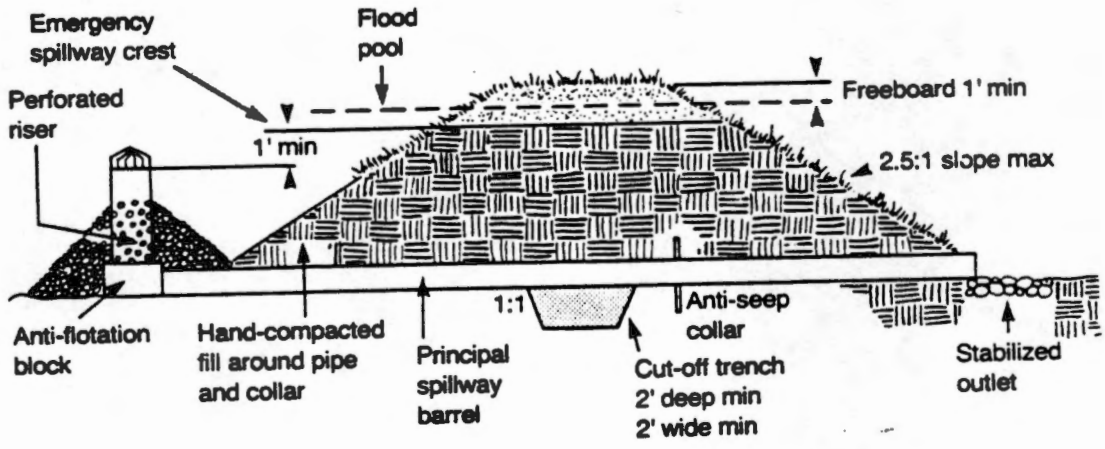


Figure 36. Section through embankment of sediment basin.

Source: North Carolina Sedimentation Control Commission, North Carolina Department of Natural Resources and Community Development, and North Carolina Agricultural Extension Service, Erosion and Sediment Control Planning and Design Manual. State of North Carolina Department of Natural Resources and Community Development, Raleigh, North Carolina (1988).

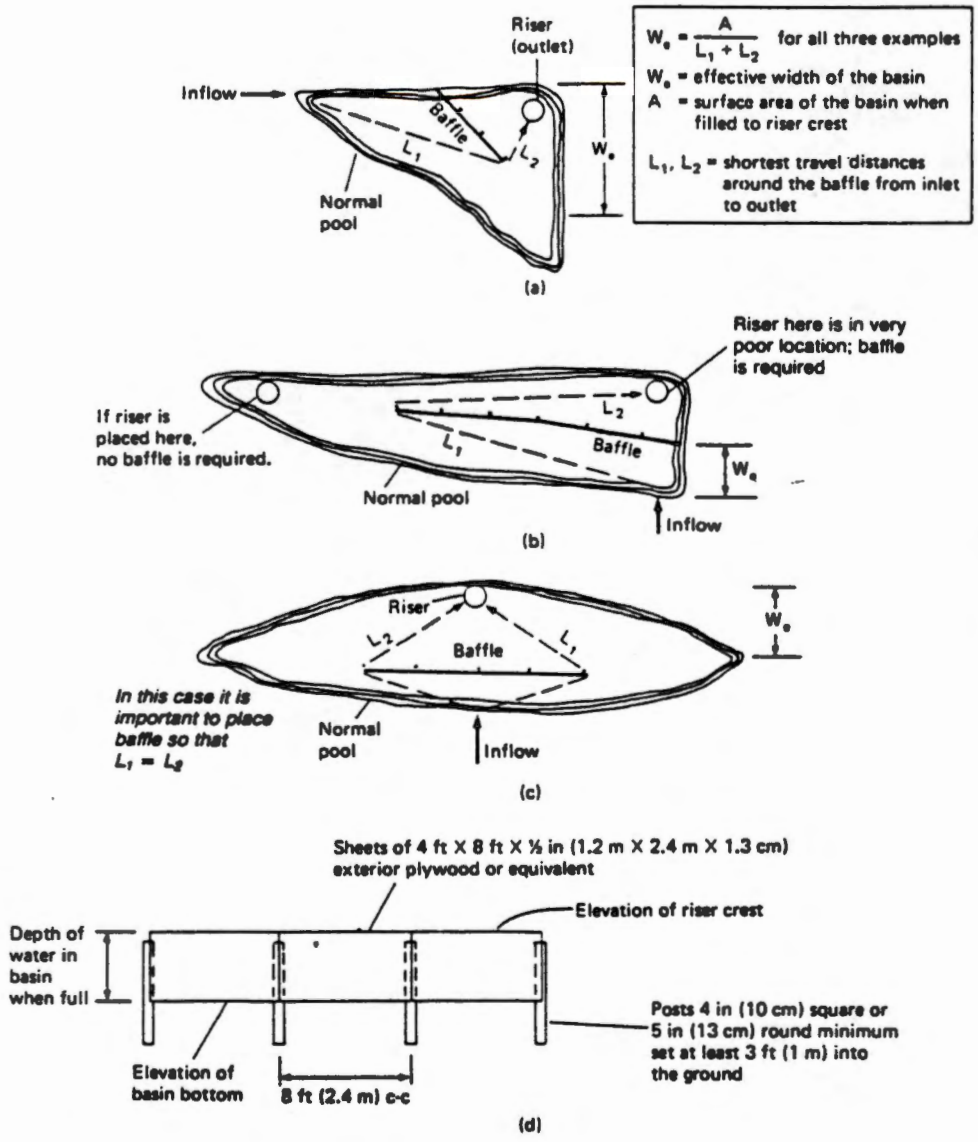


Figure 37. Three examples of settlement basin baffle placement (a-c) and baffle detail, elevation (d).

Note: Not to scale.

Source: Goldman, S.J., Jackson, K., and Bursztynsky, T., Erosion and Sediment Control Handbook. McGraw-Hill Book Company, New York, New York (1986).

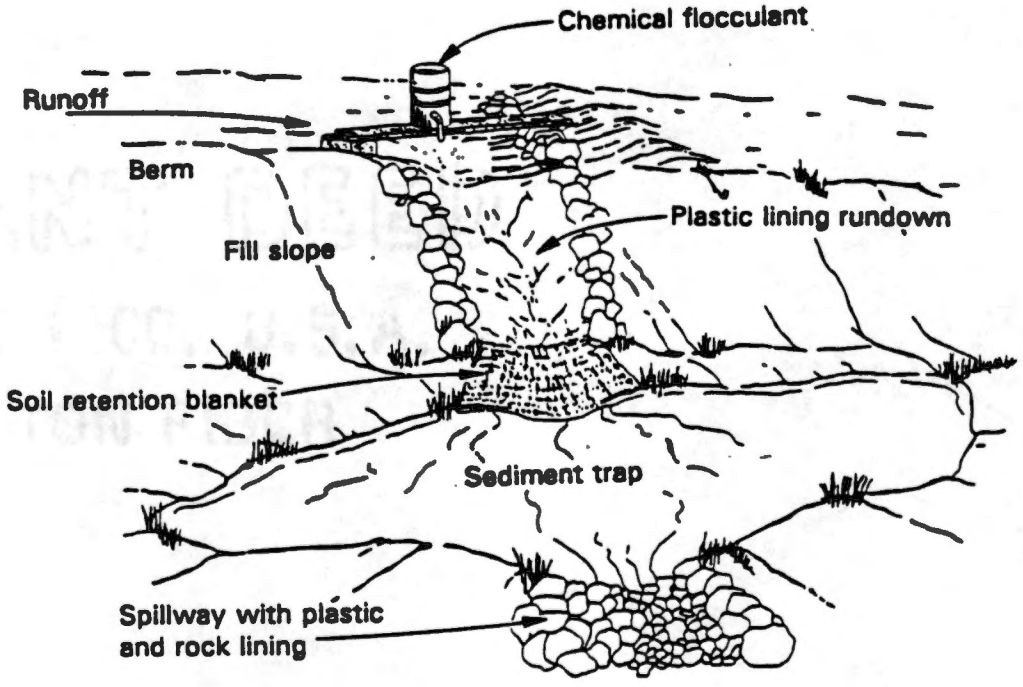


Figure 38. Chemical flocculant treatment example.

Source: Colorado Department of Highways, Erosion Control Manual. Colorado Department of Highways in cooperation with the U.S. Department of Transportation, Federal Highway Administration (1978).

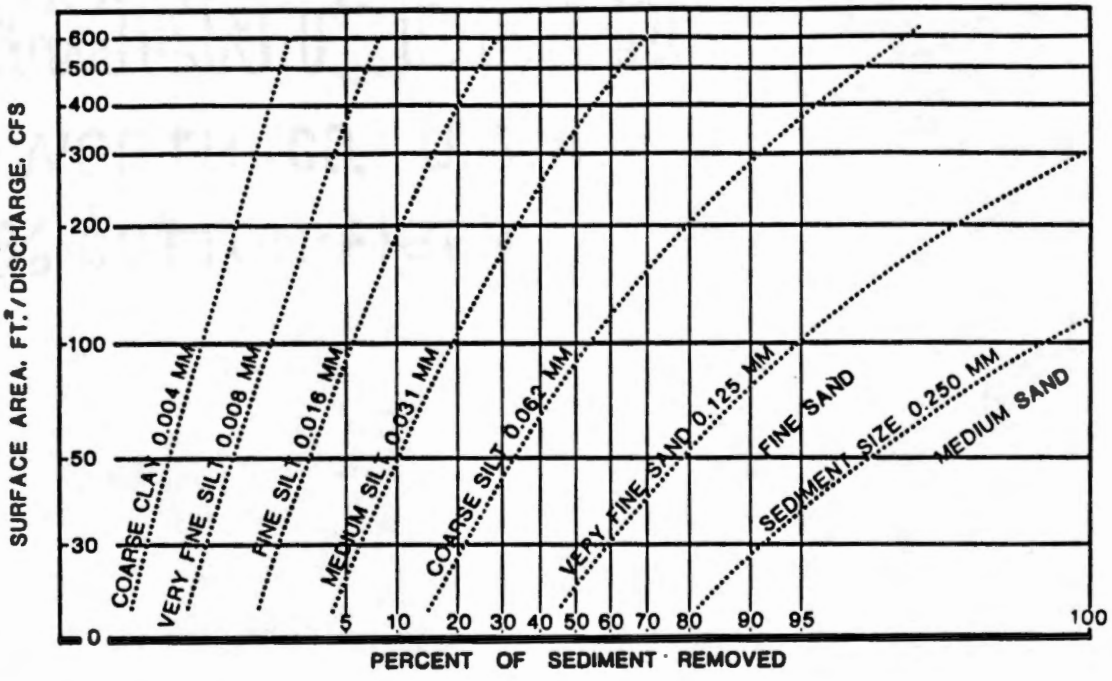


Figure 39. Percent of sediment removed for different basin sizes, sediment sizes and discharges.

Source: Colorado Department of Highways, Erosion Control Manual. Colorado Department of Highways in cooperation with the U.S. Department of Transportation, Federal Highway Administration (1978).

EMERGENCY SPILLWAY

The purpose of an emergency spillway is to provide adequate flood flow capacity without overtopping the dam. An emergency spillway should be used on a sediment basin serving a drainage area greater than 5 acres. The emergency spillway should be constructed in undisturbed soil (not fill), and capable of withstanding a 10-year peak flow. Effective emergency spillway cross sections can be saddle-shaped or trapezoidal with side slopes of 3:1 or flatter. The control section should be flat for at least 20 feet. An example emergency spillway is illustrated in Figure 40.

PRINCIPAL SPILLWAY

The purpose of a principal spillway is to provide a flow outlet for minor storm events. Principal spillways may appear in several forms and designs. The following discusses the basic design considerations for some of the most common designs.

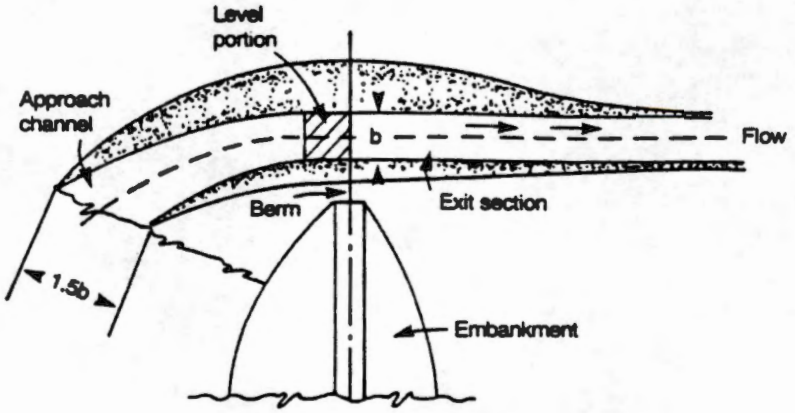
1. Usually a vertical pipe or box-type riser is jointed to a conduit (commonly called the barrel) that extends through the embankment to an outlet beyond the downstream toe of the fill (see Figure 36). Material must be able to withstand the maximum external loading without yielding, buckling, or cracking. The barrel should have water-tight joints (accomplished by use of o-rings or equivalent) to prevent piping failure from occurring. Structural spillways other than pipe should have structural designs based on sound engineering data with acceptable soil and hydrostatic loadings as determined on an individual site basis.

2. The minimum flow rate should be 0.2 cubic feet per second per acre.

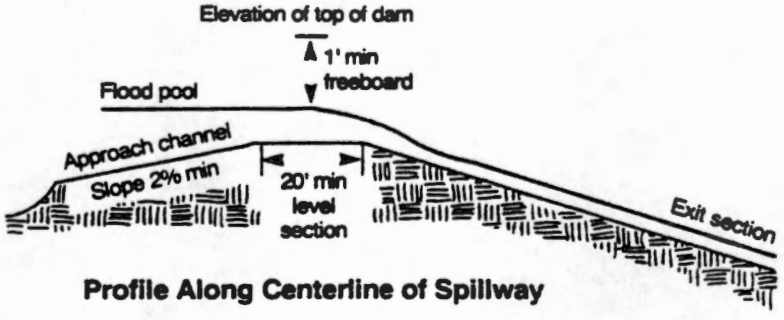
3. The minimum barrel diameter should be 8 inches and the riser cross sectional area should be at least 1.5 x barrel area.

4. The crest elevation of the riser should be a minimum of 1 foot below the emergency spillway crest.

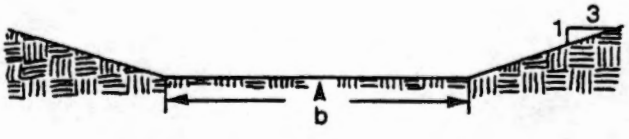
5. An anti-vortex device and trash rack should be installed on the top of the riser.



Plan view



Profile Along Centerline of Spillway



Cross-section at Control Section

Figure 40. Plan, profile, and cross section of emergency spillway excavated in undisturbed soil.

Source: North Carolina Sedimentation Control Commission, North Carolina Department of Natural Resources and Community Development, and North Carolina Agricultural Extension Service, Erosion and Sediment Control Planning and Design Manual. State of North Carolina Department of Natural Resources and Community Development, Raleigh, North Carolina (1988).

6. Anti-seep collars should be watertight and should project at least 15 inches around the barrel (see Figure 36). A minimum of one anti-seep collar should be installed at approximately midpoint of the fill; dams greater than 15 feet in height should receive at least two collars, with the second collar located at the intersection of the water surface with the fill slope.

7. Antifloatation blocks should anchor the barrel to hold the riser in place and should have a buoyant weight greater than 1.1 times the weight of water displaced by the riser and any exposed portion of barrel.

8. Detention basins should be able to completely dewater within 5 days of a storm event. This may be accomplished by using a perforated riser, a riser with one or more dewatering holes, or a small flexible line with one end attached to the riser and the other to a float. Some dewatering techniques are shown in Figure 41.

COMMON TROUBLE POINTS AND SOME CORRECTIVE MEASURES

- Piping failure along conduit; this can be caused by a lack of proper compaction, omission of an anti-seep collar, or leaking pipe joints.

- Erosion of spillway or embankment slopes; this can be caused by inadequate vegetation, improper grading and sloping, or improper slope protection.

- Slumping and/or settling of embankment; slumping can be caused by inadequate compaction and/or use of poor-quality fill material.

- Slumping failure; this is caused by having overly steep side slopes.

- Erosion and caving below pipe; this is caused by inadequate outlet protection.

- Basin not located properly for access; this makes maintenance difficult and costly.

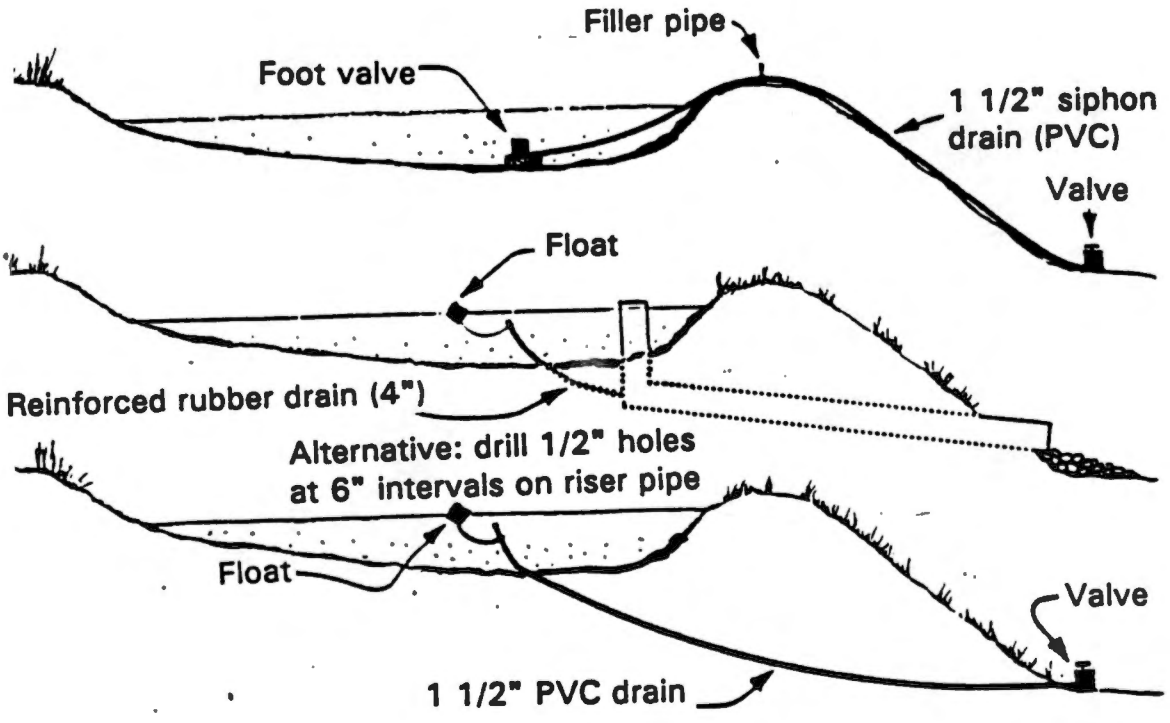


Figure 41. Various dewatering procedures.

Source: Colorado Department of Highways, Erosion Control Manual. Colorado Department of Highways in cooperation with the U.S. Department of Transportation, Federal Highway Administration (1978).

- Sediment not properly removed; this leaves inadequate storage capacity.

- Lack of trash rack; the barrel and riser may become blocked with debris.

- Sediment disposal area not designated on plans; this results in improper disposal of accumulated sediment.

- Drain pipe through dam collapses or becomes separated; this can cause a dam blowout to occur. Ensure structurally adequate pipe and water-tight joints are employed.

MAINTENANCE

Inspect sediment basins following each significant rainfall event, repairing embankment, spillway, and outlet erosion damage. Remove trash and other debris from riser, spillway, and pool area. Look for signs of piping, settlement, seepage, or slumping on the embankment and repair these problems immediately.

The cleanout elevation should be located at 50 percent of the design volume; a stake placed at this elevation can be helpful. Soils in western Tennessee are more erodible and sediment basins there may require more frequent cleaning than sediment basins in eastern Tennessee. Deposit removed sediment in designated locations.

REMOVAL

After the drainage area has been permanently stabilized, the basin may be drained, the sediment deposited in designated areas, and the site smoothed to blend with terrain or as indicated on plans.

REFERENCES

Colorado Department of Highways, 1978; Goldman et al., 1986; Knox County Soil Conservation District, 1981; North Carolina Sedimentation Control Commission et al., 1988; Tennessee Department of Transportation, 1981; and Wang and Grubbs, 1990.

SECTION VI

STREAM AND STREAMBANK PROTECTION

TEMPORARY STREAM CROSSING

DESCRIPTION

A temporary stream crossing is used to convey construction vehicles across a watercourse with minimum erosion. Temporary structures such as bridges, culverts, and fords help to prevent streambank and channel erosion by preventing direct vehicle contact with the water.

WHERE STREAM CROSSINGS ARE USED

Temporary stream crossings are used where streams or intermittent streams created during heavy rainfall would experience bank and/or streambed damage/erosion caused by crossing construction vehicles. These temporary stream crossings are used to facilitate construction needs and should not be utilized for general public traffic.

BASIC DESIGN AND CONSTRUCTION GUIDELINES

Temporary crossings should be in service for the shortest practical period possible because of the possibility that the channel constriction associated with them can cause flood backups or washouts during periods of high water flow. The structure should be nonerosive, should be structurally stable, and should not induce any flooding or safety hazard. The structure must be able to carry the load of the construction vehicles. Such structures are subject to the rules and regulations of the U.S. Army Corps of Engineers and the Tennessee Department of Environment and Conservation - Division of Water Pollution Control for in-stream modifications (section 404 and aquatic resource alteration permits) and should be designed by a qualified engineer.

Planning Considerations

If possible, construct the temporary stream crossings when stream flow is low.

Locate the crossing at a right angle with the stream and where road alignment can approach a minimum straight distance of 30 feet with the centerline. Minimize clearing and excavation of the streambanks, streambed, and approach sections.

Minimize crossing the stream bed with equipment. When possible, complete work on one side before crossing to work on the other side. Avoid diverting the stream out of its natural channel by working on one-half of the installation at a time.

All temporary stream crossings should have one lane with a minimum width of 12 feet and maximum width of 20 feet.

Bridges

Bridges pose the least potential for creating barriers to aquatic life and are favored in streams where fish spawn or migrate. Additionally, most bridges can be quickly removed and reused. Normally, bridge construction causes the least disturbance to the streambed and streambanks when compared to the other types of temporary stream crossings, but they can cause the greatest safety hazard if they are not adequately designed, installed, and maintained.

Bridges are usually constructed of wood, metal, or other materials that can span across a stream or waterway. Bridges should not cause a significant water level difference between the upstream and downstream water surface elevations.

Diversions should be installed in the road approach sections to divert runoff away from the bridge, as illustrated in Figure 42.

A temporary bridge should be constructed at or above bank elevation to prevent the entrapment of floating materials and debris.

The bridge should span the entire width of channel. If the channel width exceeds 8 feet (as measured from the top of one bank to the top of the other bank), then a footing, pier, or bridge support may be constructed within the waterway with additional footings for each additional 8-foot width of channel. No footing, pier, or bridge support should be permitted within the channel for waterways narrower than 8 feet.

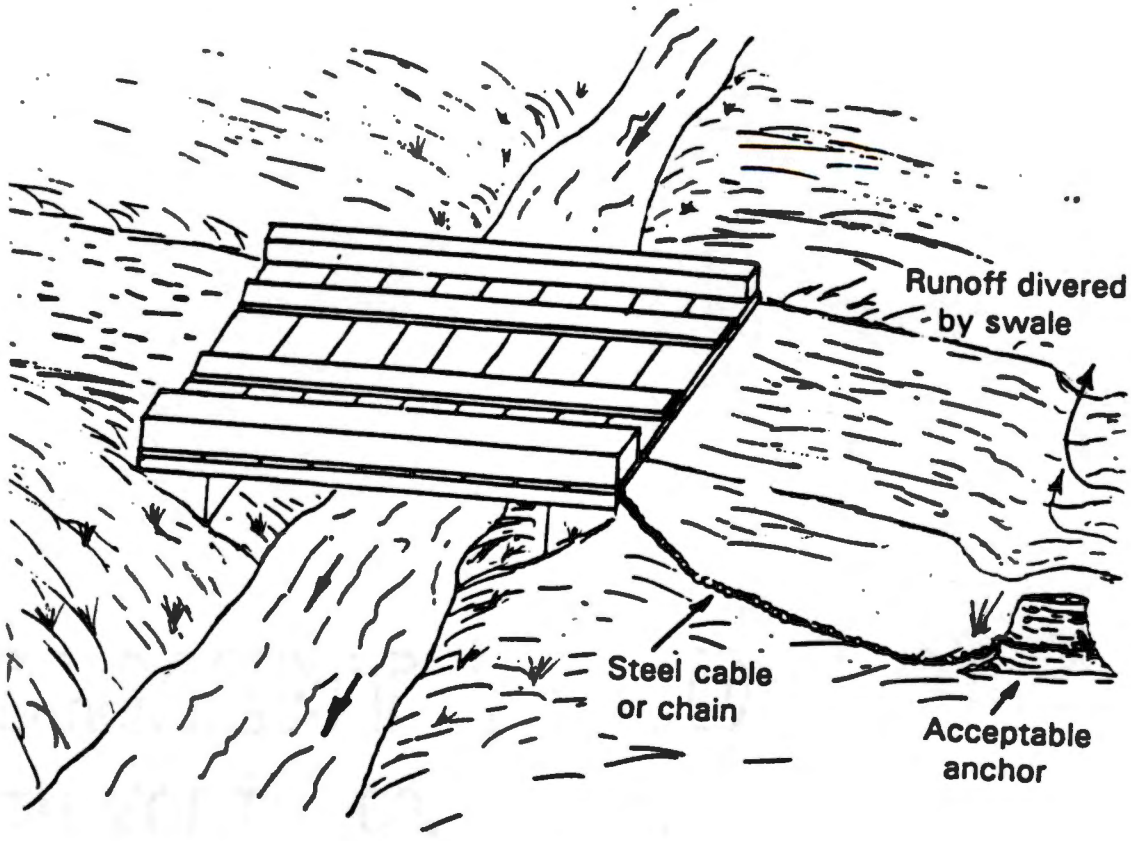


Figure 42. Example of a temporary access bridge.

Source: Maryland Department of the Environment, Soil Conservation Service, and State Soil Conservation Committee, 1983 Maryland Standards and Specifications -- For Soil Erosion and Sediment Control. Maryland Department of the Environment, Baltimore, Maryland (1983).

Stringers should either be logs, sawn timber, prestressed concrete beams, metal beams, or other approved materials. Decking material should be of sufficient strength to support the anticipated load. All decking members should be placed perpendicular to the stringers, butted tightly (to prevent any soil material tracked onto the bridge from falling into the waterway below), and securely fastened to the stringers.

Run planks, when used, should be securely fastened the length of the span. One run plank should be provided for each track of the equipment wheels. Run planks are sometimes necessary to properly distribute loads. Curbs or fenders may be installed along the outer sides of the deck to provide additional safety.

Bridges should be anchored at only one end using a steel cable or chain, as shown in Figure 42. Anchoring at only one end will prevent channel obstruction in the event that flood waters float or dislodge the bridge. Acceptable anchors are large trees, large boulders, or driven steel anchors. Anchoring should be sufficient to prevent the bridge from floating or migrating downstream and causing possible obstruction to the flow.

All areas disturbed during installation should be properly stabilized immediately.

Culverts

Clean crushed stone should be used to form a temporary construction culvert crossing; otherwise protect fill slopes, streambanks, and overflow areas with riprap or other suitable methods. Diversions should be installed in road approach sections to divert runoff away from the structure. The following rule-of-thumb table may be used in combination with sound engineering design analysis to approximate the proper size of culvert.

Pipe Diameter For Stream Crossings (inches)

Drainage Area (acres)	Average Slope of Watershed 1%	4%	8%	16%
1-25	24	24	30	30
26-50	24	30	36	36
51-100	30	36	42	48
101-150	30	42	48	48
151-200	36	42	48	54
201-250	36	48	54	54
251-300	36	48	54	60
301-350	42	48	60	60
351-400	42	54	60	60
401-450	42	54	60	72
451-500	42	54	60	72
501-550	48	60	60	72
551-600	48	60	60	72
601-640	48	60	72	72

Assumptions for determining the table: USDA-SCS peak discharge method; CN = 65; rainfall depth = 3.5" for 2-year frequency storm.

Multiple culverts may be used in place of one large culvert if they have the equivalent capacity of the larger one, but they should not be less than 18 inches in diameter and should be spaced a minimum of 6 inches apart. Minimum height of cover over the culvert should be one-half the diameter or 12 inches, whichever is greater. A culvert design example is illustrated in Figure 43.

The minimum slope of the culvert should be at least 0.25 inch per foot with the length extending the full width of the crossing (including side slopes). The culvert should be placed as close as possible to the streambed to prevent impoundment. The outlet should be stabilized to prevent erosion and/or scour.

Fords

Fords are effective for infrequent crossing of wide, shallow streams but are not recommended due to possible sediment loads on

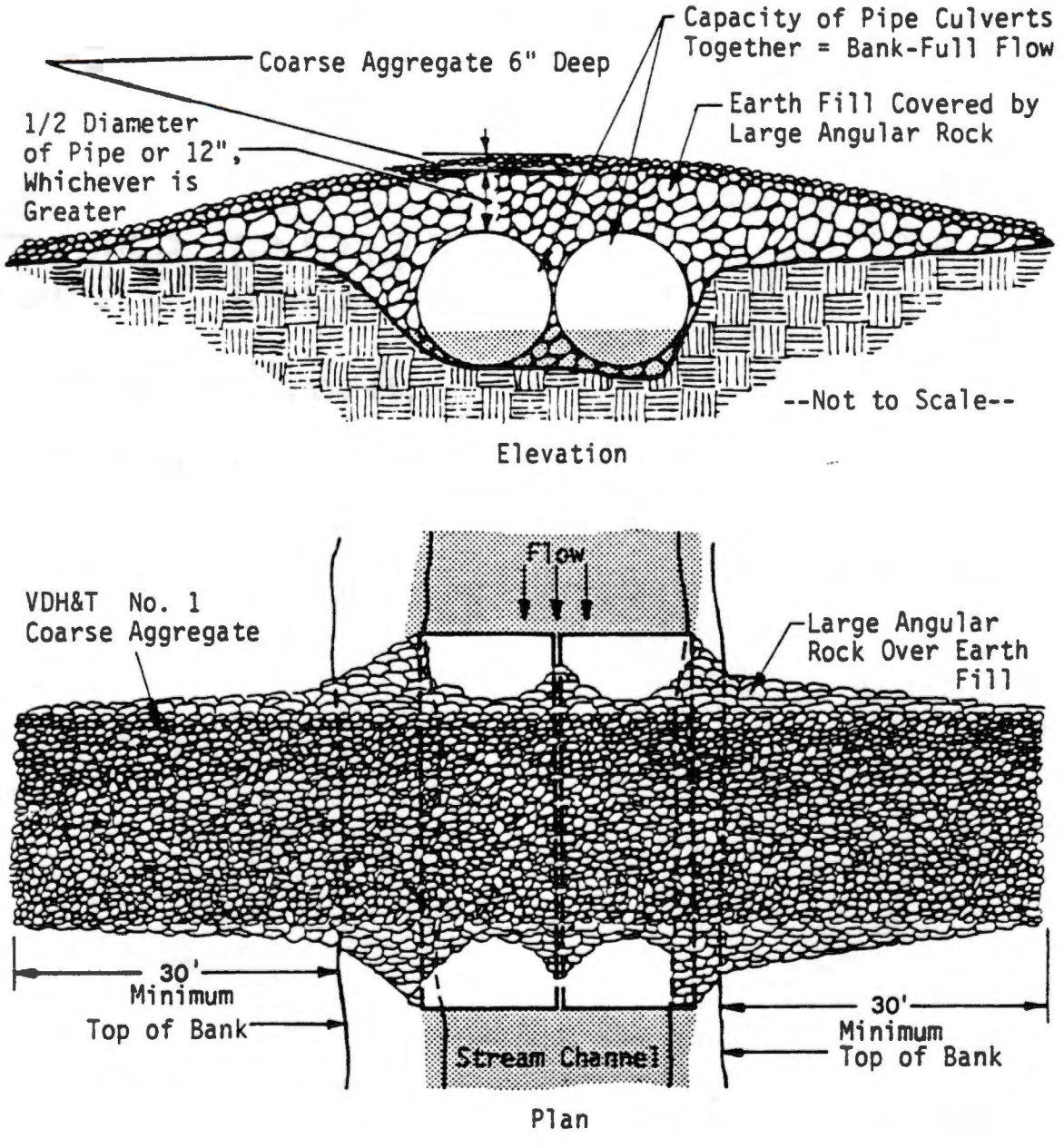


Figure 43. Example of temporary culvert stream crossing.

Source: Virginia Soil and Water Conservation Commission, Virginia Soil and Erosion Control Handbook, Second Edition. Virginia Soil and Water Conservation Commission, Richmond, Virginia (1980).

the channel caused by sediment-laden vehicles direct contact with the channel water. If fords are used, the following guides should be observed.

Install diversions in road approach sections to divert sediment-laden surface runoff to designated treatment areas (such as sediment basins), as shown in Figure 44.

When excavation of banks is necessary, bank height should not exceed 5 feet and have side slopes of 2:1 or flatter. When feasible, install in-stream sediment traps before excavating approach sections to the ford.

Install a geotextile stabilization fabric (not filter fabric) in the channel to stabilize the foundation, then apply well-graded, weather-resistant stone (3-6 inches) over the fabric.

REMOVAL

Leave in-stream sediment traps in place during removal of the temporary stream crossings. Remove temporary stream crossings as soon as they are no longer needed. Restore stream channel to original cross section and stabilize all disturbed areas. Fords may be left in place if site conditions allow.

COMMON TROUBLE POINTS AND SOME CORRECTIVE MEASURES

- Inadequate flow capacity and/or lack of overflow area around structure; this results in washout of culverts or bridge abutments.

- Inadequate stabilization of overflow area; this results in severe erosion around bridges and culverts.

- Exit velocity from culvert or bridges too high; high exit velocity causes stream channel erosion and may eventually cause erosion of bridge abutments/piers or culvert fill.

- Debris not removed after a storm; debris clogging may cause washout of culverts or bridges.

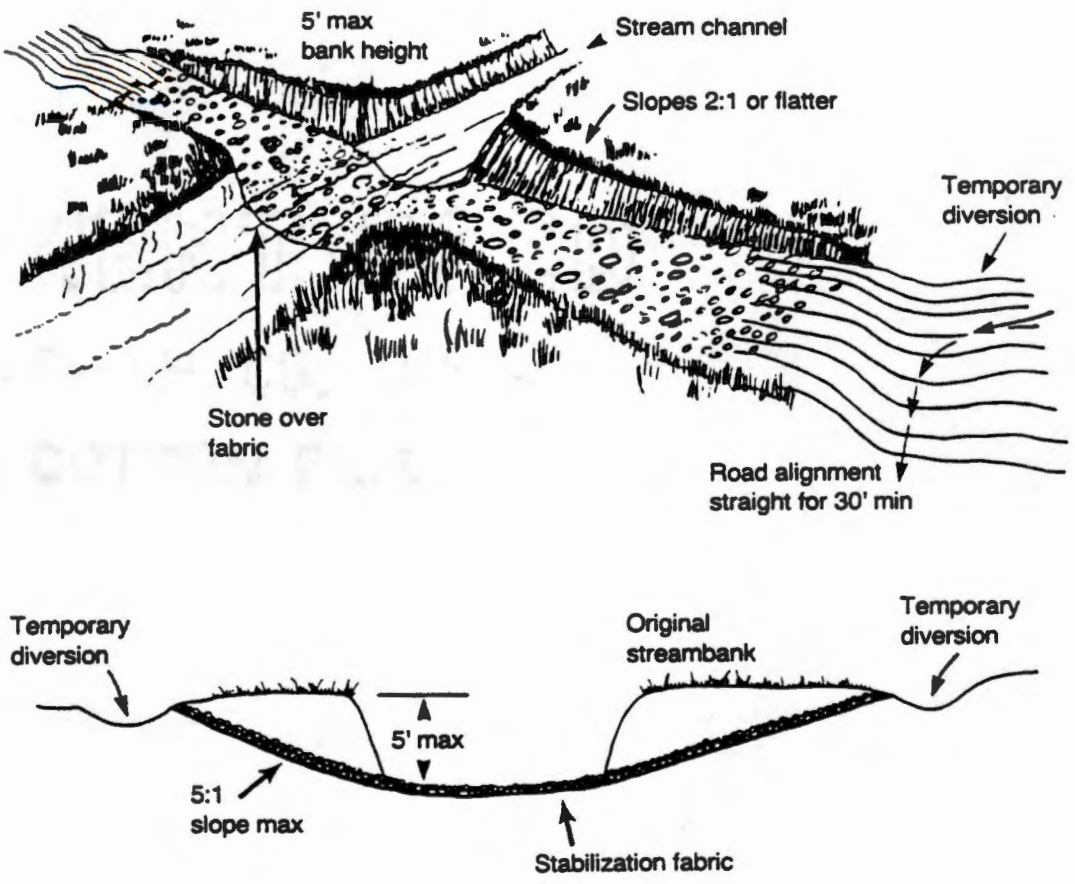


Figure 44. Ford stabilized with stone over stabilization fabric.

Source: North Carolina Sedimentation Control Commission, North Carolina Department of Natural Resources and Community Development, and North Carolina Agricultural Extension Service, Erosion and Sediment Control Planning and Design Manual. State of North Carolina Department of Natural Resources and Community Development, Raleigh, North Carolina (1988).

- Inadequate compaction under or around culvert pipe; culverts wash out due to seepage and piping.

- Stone size too small; a ford can wash out.

- Culvert pipes too short; use of too short pipes results in a crossing supported by steep, unstable fill slopes.

MAINTENANCE

Inspect temporary crossings after each rainfall event for accumulation of debris, blockage, erosion of abutments and overflow areas, channel scour, riprap displacement, or piping along culverts. Remove debris; repair and reinforce damaged areas immediately to prevent further damage to the installation.

REFERENCES

Maryland Department of the Environment et al., 1983; North Carolina Sedimentation Control Commission et al., 1988; Virginia Soil and Water Conservation Commission, 1980; and Wang and Grubbs, 1990.

TEMPORARY STREAM DIVERSION

DESCRIPTION

Temporary stream diversions are used to divert or reduce stream flow from a critically erodible area disturbed by construction within the normal stream path until such areas can be stabilized.

WHERE TEMPORARY STREAM DIVERSIONS ARE USED

- Used when construction within a full flowing stream could create severe environmental impacts due to potential erosion and the resulting sedimentation.

- Used when any construction activity is necessary within a stream, such as piers, abutments, and/or bank stabilization.

- Used when high waters due to heavy rains could cause damage to construction areas in/beside the stream.

BASIC DESIGN AND CONSTRUCTION GUIDELINES

Planning Considerations

Place erosion control devices in place prior to construction. All materials should be on-site before work begins. All excavated material should be disposed of in an approved disposal area outside the 100-year floodplain. When dewatering the construction area, sediment-laden water should be pumped to a dewatering basin prior to stream reentry. Sediment removal in the basin must be sufficient so that released water is as clear or clearer than receiving stream.

Partial Stream Diversion

Materials used in a partial stream diversion should consist of sandbags, stone, sheeting (such as polyethylene), and/or other suitable material that is capable of diverting a segment within the stream. A sandbag/stone stream diversion is illustrated in Figure 45. Material used, when applicable, should be resistant to ultraviolet radiation,

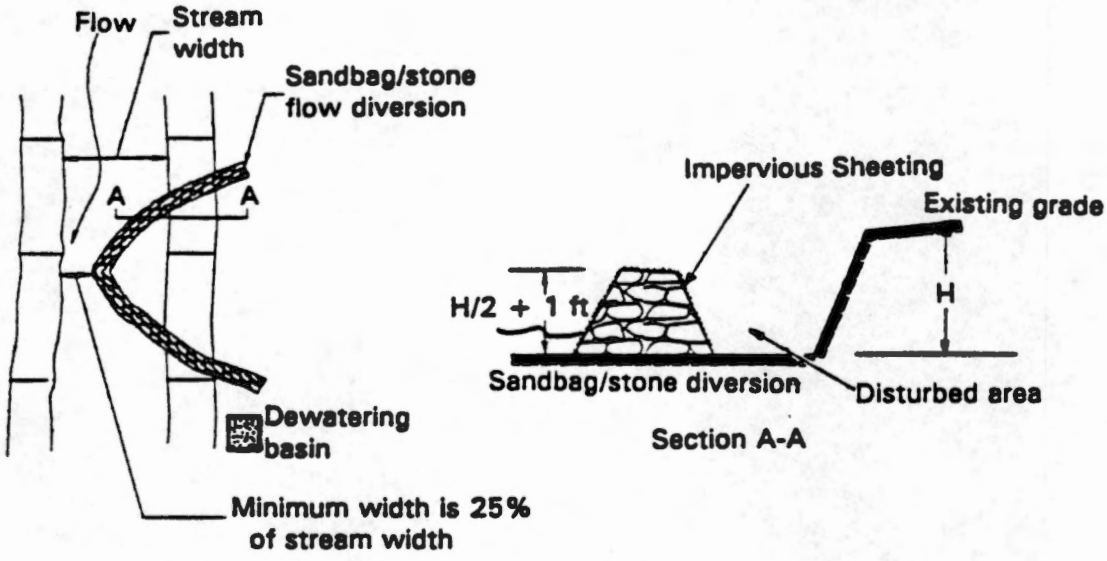


Figure 45. Stream diversion using sandbags or stone.

Source: Maryland Department of the Environment, Soil Conservation Service, and State Soil Conservation Committee, 1983 Maryland Standards and Specifications -- For Soil Erosion and Sediment Control. Maryland Department of the Environment, Baltimore, Maryland (1983).

tearing and puncture, and should be woven tightly enough to prevent leakage of fill material. Materials should be installed from upstream to downstream.

The diverted stream's height should not exceed the stream's 2-year/24-hour frequency storm depth, nor should the stream be allowed to overflow the bank of the channel.

If the stream needs to be diverted more than 75 percent of its width, then the Temporary Bypass Channel criteria as listed below should be followed.

In small channels not covered by a waterway construction permit, the height of the diversion may be one foot higher than the lowest bank elevation if a stable overflow area is provided, otherwise the height should not exceed one-half the distance from streambed to the streambank plus 1 foot.

Temporary Bypass Channel

A temporary bypass channel should be stable for flows up to and including that expected in a 25-year/24-hour frequency storm. The stream should be diverted with minimum excavation, clearing, grubbing, and embankment fills. Temporary Slope Drains (see Section IV) are sometimes substituted to convey water in low flow streams within drainage areas of 5 acres or less provided they pose no threat to aquatic life.

Excavation of the bypass channel should start at the downstream end and proceed upstream. All excavated material should be stockpiled outside the 100-year floodplain and stabilized to prevent entry into the stream. Side slopes should not exceed 2:1. The process of excavation and stabilization (with fabric and/or riprap) should be a continuous process.

When fabric is used, it should have a continuous width wide enough to allow it to lay flush with the canal at all points, and the fabric should be keyed (anchored) at the top of the streambank. Upstream sections should overlap downstream sections a minimum of 2 feet. Additionally, the fabric should be keyed with riprap in approximately 2 foot x 2 foot trenches that extend the channel's width

at the upstream entrance and at 50 foot intervals. Overlaps should be pinned with minimum 18 inch long staples and spaced a minimum of 3 feet apart. Pins may not be necessary when riprap lining is used.

The downstream and upstream connection to the natural channel should be performed under dry conditions and may be so accomplished by use of sandbag diversions. Figure 46 illustrates a temporary stream diversion channel design.

COMMON TROUBLE POINTS AND SOME CORRECTIVE MEASURES

- Stream velocity exceeds that allowable for the temporary channel; stabilize the channel with appropriate sized riprap.

- Washout of partial stream diversion; the diversion is not properly stabilized or installed. Reevaluate the design.

- Fabric not wide enough to be continuous over the width of the channel; some fabrics may be sewn together and will work equally well.

- Re-establishment of stream in bypass after the bypass was backfilled; the backfill and stabilization was not done properly. Points of tie-in with the natural channel may require additional stabilization.

MAINTENANCE

Check stream diversions following each storm event, including those that occur in areas upstream yet have significant effect on downstream flow. Repair damaged areas and replace displaced riprap and/or sandbags immediately.

REMOVAL

Leave in-stream sediment traps in place during removal of the temporary stream diversion. Remove stream diversions as soon as they are no longer needed. Restore stream channel and stabilize all disturbed areas. Temporary bypass channels should be backfilled and properly stabilized to prevent the stream from reestablishing the path.

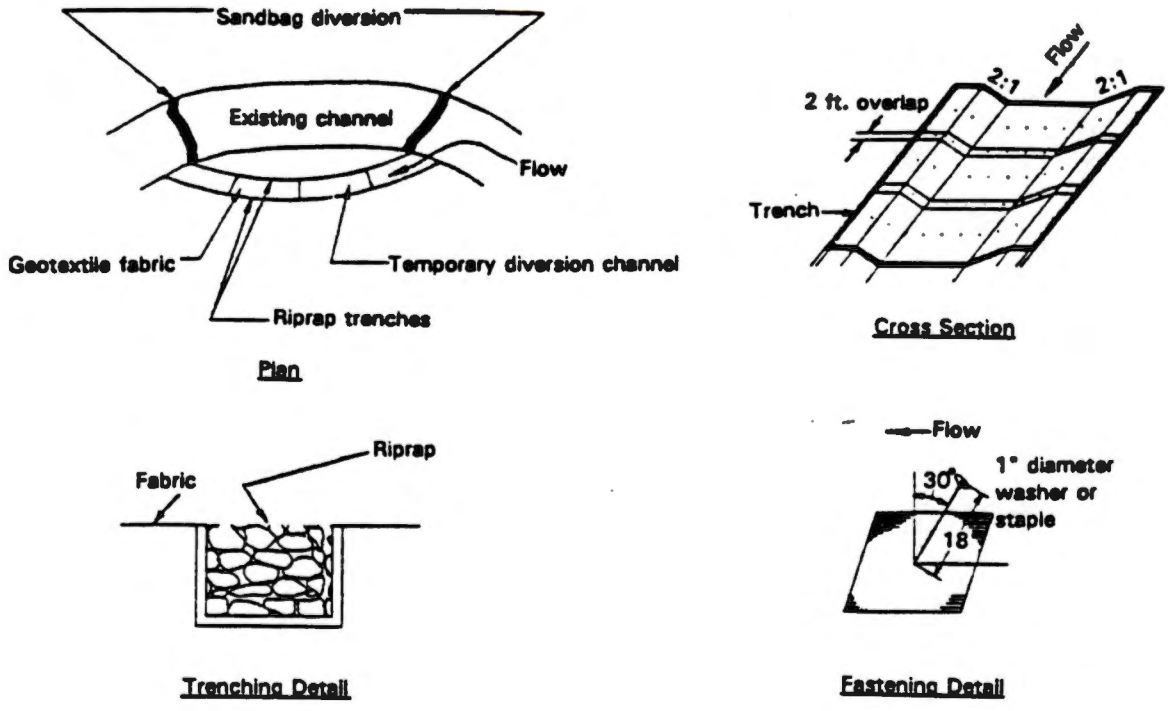


Figure 46. Temporary stream diversion channel.

Source: Maryland Department of Transportation, Erosion and Sediment Control, Revised (1989).

REFERENCES

Maryland Department of Transportation, 1989; Tennessee Department of Transportation, 1981.

RIPRAP

DESCRIPTION

Riprap is stone or rock placed to protect slopes, streambanks, channels, or other areas subject to erosion.

WHERE RIPRAP IS USED

- On streambanks or other areas subject to wave action.
- In channels where infiltration is desirable, but velocities are too excessive for vegetative lining.

toundercutting.• Around inlets or outlets prevent scour and

BASIC DESIGN AND CONSTRUCTION GUIDELINES

A high quality riprap is masonry stone that is sound, dense, and durable. Riprap should be free from excessive cracks, pyrite intrusions, and other structural defects. Stones that will be used with mortar should be free from dirt, oil, or other material that might prevent good adhesion with the mortar.

Riprap and gabions are commonly employed an streambanks for stabilization purposes. Riprap may be used on slopes of 1.5:1 or flatter. Gabions (stone-filled wire baskets) are suggested when slopes exceed 1.5:1. Gabions are baskets with compartments made of hexagonal galvanized steel mesh, generally filled with 4 to 8 inches of stone or larger. Gabions are generally fastened together to form desired slope shape.

The size and type of riprap is dependent on certain site characteristics such as velocity, wave action, and condition of the subgrade. Although an area to receive riprap should be designed by a qualified engineer, a general guide for size selection based on velocity and/or wave action was developed by the National Stone Association (NSA) and is shown in Table 2. Note that the table gives and "average" as well as a maximum and minimum size. This average,

Table 2. Riprap and filter stone sizing for given velocities and wave heights.

Quarried Stone for Erosion & Sediment Control (5)

GRADED RIPRAP STONE

NSA No.	Size inches (sq. openings) Max.	Avg. (1)	Min. (2)	Wave Height (3) (ft.)	Velocity (4) (ft./sec.)	Filter Stone NSA Size No.
R-1	1½	¾	(No. 8)	—	2.5	FS-1
R-2	3	1½	1	0.3	4.5	FS-1
R-3	6	3	2	0.5	6.5	FS-2
R-4	12	6	3	1.0	9.0	FS-2
R-5	18	9	5	1.5	11.5	FS-2
R-6	24	12	7	2.0	13.0	FS-3
R-7	30	15	12	2.5	14.5	FS-3
R-8	48	24	15	4.0	—	FS-3

ARMOR STONE*

NSA No.	Wt. in Short Tons Max.	Avg.	Min. (2)	Wave Height (ft.)(6)	Filter Stone
A-1	4.0	3.0	2.0	8.0	(See supplemental engineering notes)
A-2	6.0	4.5	3.0	10.0	
A-3	8.0	6.5	5.0	12.0	

*One or more underlayers may be required in addition to stone filter.

FILTER STONE

NSA No.	Size inches (sq. openings) Max.	Avg.	Min. (2)
FS-1	⅜	No. 30	No. 100
FS-2	2	No. 4	No. 100
FS-3	6½	2.5	No. 16

Figure A*

Notes: (1) "Average size" is that size exceeded by at least 50 percent of the total weight of the tonnage shipped; i.e., 50 percent of the tonnage shall consist of pieces larger than the "average" size (normally half the specified nominal top size).

(2) Pieces smaller than the minimum size shown shall not exceed 15 percent of the tonnage shipped.

(3) Wave height is the vertical distance from wave crest to wave trough. The wave height given in the table is the average height of the one-third highest waves in the incident wave train.

(4) The stream velocity is the velocity at mid-stream or at a point 10 feet from the bank, whichever is closest to the bank.

(5) The table assumes a stone dry density of 165 pounds per cu. ft.

(6) The stone industry generally is unable to economically produce armor stone in sizes to fit the 6-ft. wave height category. Therefore, the reader should use NSA No. A-1.

Source: National Stone Association, Quarried Stone for Erosion and Sediment Control, 1415 Elliot Place, N.W., Washington, D.C. (January, 1989).

defined as that size exceeded by at least 50 percent of the total tonnage shipped, is the most important governing factor in selecting the proper size designation for the give wave height or stream velocities. Even though all pieces might be larger than the minimum size of a particular designation, if the average size is too small, the installation might not function as intended.

A filter layer is sometimes necessary on certain types of subgrades. The NSA has also developed a set filter stone size to correspond with each suggested riprap size (see Table 2). Note that NSA is one of several procedures developed for riprap and corresponding filter size design.

Placement

Clear the area to receive riprap of all brush, trees, stumps, and other objectionable material. Exercise care in the preparation of the riprap subgrade to ensure that no reduction in the design waterway occurs. Riprap should be placed to blend with the surrounding topography as shown in Figure 47. Riprap should be keyed in when used as slope protection as illustrated in Figure 48, where T is the designed thickness of the riprap and the key depth is 1.5 T.

If a filter blanket or sand/gravel filter on subgrade is required, it should be placed as shown on plans. Care should be taken to place riprap in such a manner as to avoid displacing or tearing of the filter. When a filter is not required, the subgrade should be compacted as to prevent undercutting or slumping from occurring.

Riprap may be dumped and placed by the use of appropriate power equipment in a manner that will produce a surface uniform in appearance. Hand work may be required to correct irregularities. Some other various riprap procedures are as follows:

Rubble-Stone Riprap (Plain)

Rubble-stone riprap should consist of at least 90 percent of the stone not less than 8 inches wide by 12 inches long by 12 inches deep and should be approximately rectangular in shape. Rubble-stone should be hand placed so that the stones are close together, are staggered at all joints as far as possible, and are placed so as to reduce

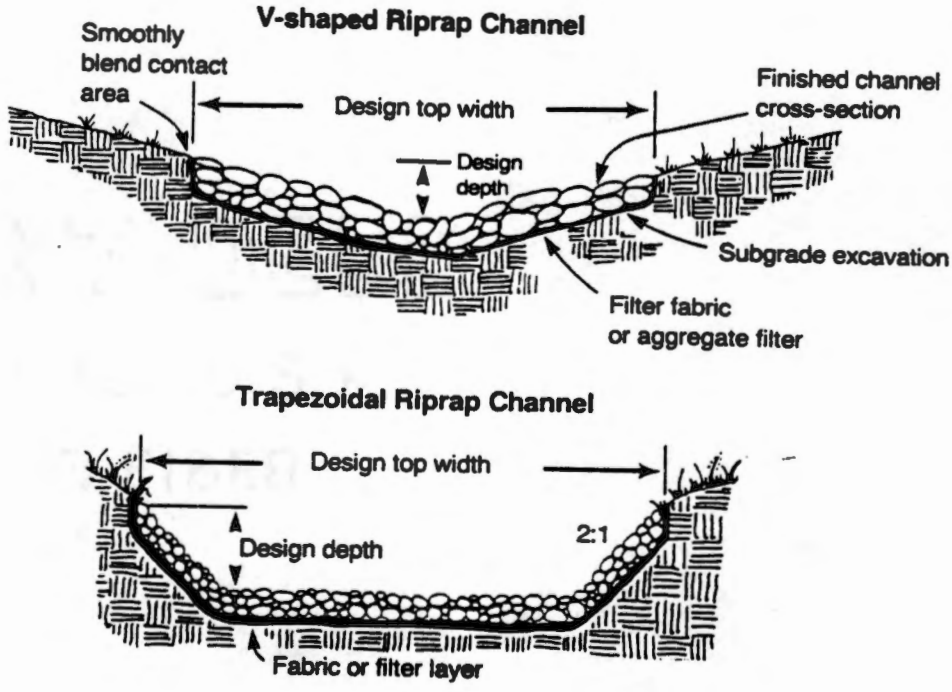


Figure 47. Finished riprap surface should blend with surrounding land surface.

Source: North Carolina Sedimentation Control Commission, North Carolina Department of Natural Resources and Community Development, and North Carolina Agricultural Extension Service, Erosion and Sediment Control Planning and Design Manual. State of North Carolina Department of Natural Resources and Community Development, Raleigh, North Carolina (1988).

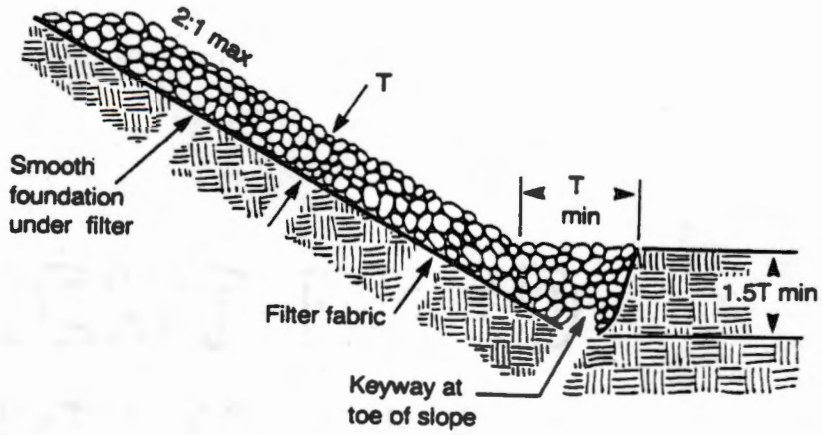


Figure 48. Riprap slope protection.

Source: North Carolina Sedimentation Control Commission, North Carolina Department of Natural Resources and Community Development, and North Carolina Agricultural Extension Service, Erosion and Sediment Control Planning and Design Manual. State of North Carolina Department of Natural Resources and Community Development, Raleigh, North Carolina (1988).

the voids to a minimum. The main stone should be thoroughly "chinked" and filled with the smaller stones by throwing them over the surface in any manner that is practical for the smaller stones to fill the voids.

The standard depth should be 12 inches, but at no case should it be less than 10 inches deep. The average depth should not be less than the required depth and is determined from evaluation of a 25 square foot surface area.

When rubble-stone riprap is constructed in layers, the layers should be thoroughly tied together with large stones protruding from one layer into the other.

Stones that protrude more than 4 inches of what is considered normal surface of the stones should be broken down to come within 4 inches of the normal surface.

Rubble-Stone Riprap (Grouted)

Stone placement for rubble-stone riprap (grouted) is the same as for rubble-stone riprap (plain). The grouting procedure is as follows:

When grouting is used, care should be taken to prevent earth or sand from filling the spaces between the stones before the grout is poured. Grout should be composed of one part portland cement and four parts of sand, measured by volume, and mixed thoroughly with sufficient water to a consistency that it will flow into and completely fill the voids.

Immediately before pouring the grout, the stones should be wetted by sprinkling. Beginning at the lower portion of the riprap, the grout should be carefully poured into the voids between the stone and at a slow enough rate to prevent oozing to the surface. The pouring of the grout should be accomplished by the use of vessels of adequate size and shape. Broadcasting, slopping, or spilling of grout from the vessels on the surface of the riprap is not recommended.

As soon as any section of the grouted riprap has hardened sufficiently, it should be kept moist with water that is free from salt or alkali for a period of not less than 72 hours.

Sacked Sand-Cement Riprap

Sand for sacked sand-cement riprap may be manufactured or natural mixed with a high quality hydraulic cement. The sand and cement should be mixed dry, with a mechanical mixer, in the proportion of one bag (94 pounds) of cement to 5 cubic feet of dry sand, until the mixture is uniform in color. The sand-cement mix should be poured into sacks of approximately 1 cubic foot capacity until they are approximately three-fourths full. Sacks should be of either cotton or jute standard grade of cloth which will hold the sand-cement mixture without leakage during handling and tamping. The sacks should then be securely fastened with hog rings, by sewing, or by other suitable methods that prohibit leakage of the mixture from the bags.

The sacks of sand-cement should be bedded by hand on the prepared grade with all the fastened ends on the grade and with the joints broken. The completed riprap should have a minimum thickness of 10 inches with a tolerance of 3 inches.

The sacks should be rammed and packed against each other in such a manner as to form close contact and secure a uniform surface. Immediately after tight placement, the sacks of sand-cement should be thoroughly soaked by sprinkling with water. Water should not be applied under high pressure. Sacks that are ripped or broken in placement should be removed and replaced before being soaked with water.

COMMON TROUBLE POINTS AND SOME CORRECTIVE MEASURES

- Displacement of riprap after a storm; slope too steep and/or stone too small. Replace with larger stone and/or decrease slope steepness.

- Scour occurs beneath the riprap; an improper type of filter cloth has been used, there is an improperly graded layer of sand or gravel, or there has been improper compaction of soil beneath the riprap. If filter cloth was used, check to see if the ends of the fabric are buried so water cannot flow underneath the fabric.

- Riprap blocks channel resulting in erosion along edge; the excavation was not deep enough for riprap placement.

- Riprap not properly graded; improperly graded riprap results in stone movement and erosion of foundation.

MAINTENANCE

When properly placed, riprap lining requires little or no maintenance. Checked after a major storm event for slumping or displacement and check to see if scour has occurred under the riprap.

Riprap should be checked at least twice during the growing season for potential brush growth. Brush should be cleared before costly removal becomes necessary.

REFERENCES

Goldman et al., 1986; National Stone Association, 1989; North Carolina Sedimentation Control Commission et al., 1988; and Tennessee Department of Transportation, 1981.

SECTION VII

CONSTRUCTION VEHICLES CONSIDERATIONS

TEMPORARY CONSTRUCTION ROAD STABILIZATION

DESCRIPTION

The temporary stabilization of an area subjected to construction traffic is used to reduce sediment leaving a site via construction vehicles and to reduce erosion of the road face.

WHERE ROAD STABILIZATION IS USED

Road stabilization is used at any location where traffic will be leaving or entering a construction site. Temporary construction entrances can help keep sediment transported by construction equipment on-site. This practice is also desirable to prevent erosion of temporary roads until they are permanently stabilized.

BASIC DESIGN AND CONSTRUCTION GUIDELINES

Place stone to dimensions and grade shown on plans, which should meet or exceed the minimum requirements indicated in Figure 49. Leave surface smooth and sloped for drainage. Divert runoff and drainage from the stone pad to a designated sediment trap/basin.

If the slope toward the road exceeds 2 percent, a 6 to 8 inch diversion ridge and/or swale (dip) should be constructed across the stabilized area approximately 15 feet from the entrance to divert runoff to a designated area (note Figure 50 for ridge example).

Place geotextile fabric on graded foundation to improve stability, especially where wet conditions are anticipated. Pipe may be installed to help maintain proper drainage.

COMMON TROUBLE POINTS AND SOME CORRECTIVE MEASURES

- Sediment washes onto public roads; the drainage system was improperly installed. Check ridge or swale for deficiencies and correct immediately.

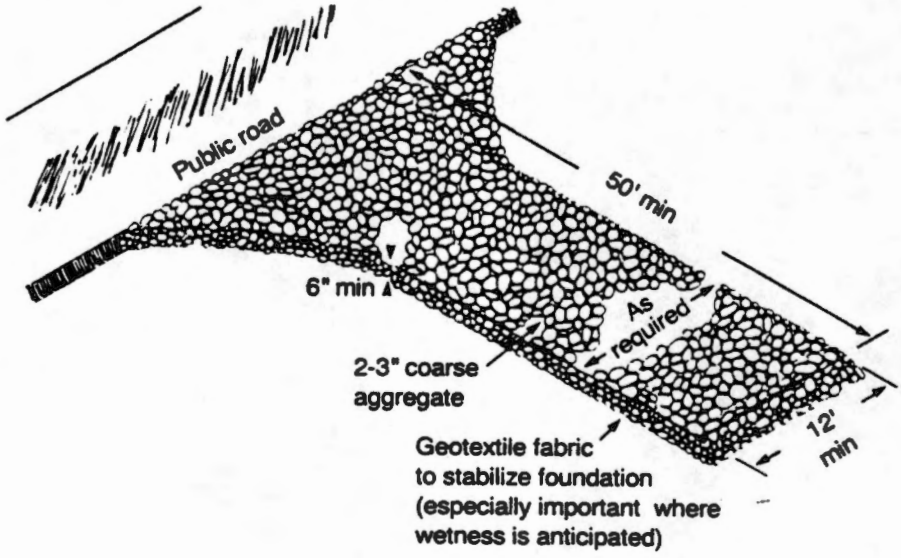


Figure 49. Plan of temporary construction entrance/exit.

Source: North Carolina Sedimentation Control Commission, North Carolina Department of Natural Resources and Community Development, and North Carolina Agricultural Extension Service, Erosion and Sediment Control Planning and Design Manual. State of North Carolina Department of Natural Resources and Community Development, Raleigh, North Carolina (1988).

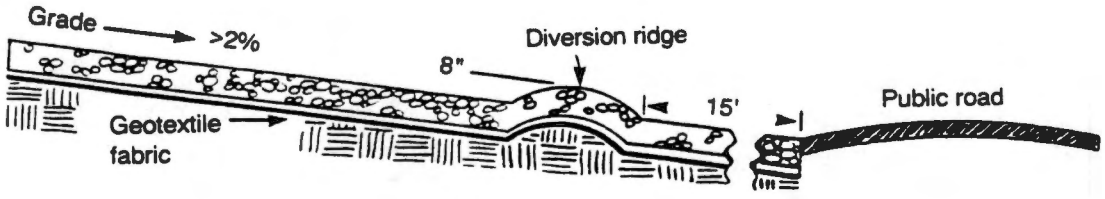


Figure 50. Design example of temporary gravel construction entrance/exit with diversion ridge where grade exceeds 2%.

Source: North Carolina Sedimentation Control Commission, North Carolina Department of Natural Resources and Community Development, and North Carolina Agricultural Extension Service, Erosion and Sediment Control Planning and Design Manual. State of North Carolina Department of Natural Resources and Community Development, Raleigh, North Carolina (1988).

- Temporary gravel entrance becomes muddy; stone is pressed into soil due to pad being too thin, the stone applied was too small, and/or the geotextile fabric was not used. Reconstruct temporary entrance.

- Sediment is tracked onto road by construction equipment; extend the pad beyond the minimum 50 foot length until condition is corrected.

- Pad not flared sufficiently at road entrance; this may result in mud being tracked onto road and possible damage to road edge.

- Unstable foundation; use geotextile fabric under pad and/or improve foundation drainage.

MAINTENANCE

Maintain entrance conditions to prevent tracking or flowing of sediment onto public roads. This may require periodic top dressing with additional stone or additional length as conditions demand and repairs and/or cleanout of any methods used to trap sediment. Remove mud and sediment tracked or washed onto public roads immediately.

REFERENCES

New Jersey Department of Transportation, 1989; and North Carolina Sedimentation Control Commission et al., 1988.

SUMMARY

Large exposed areas, long exposure times, and steep slopes commonly create the potential for soil erosion problems. The first basic principle of soil erosion/sediment control is to prevent or minimize on-site erosion by providing immediate protective cover (either vegetative or structural), minimizing the denuded area size, minimizing exposure times, and using the various management techniques to minimize scour by reducing runoff velocities and volume. When the erosion process cannot be prevented, the second basic principle of sediment control should be implemented. This practice involves trapping the sediment on-site through employment of effective management practices. As can be seen by the common trouble points associated with some of these practices, effectiveness of controls is often significantly reduced when maintenance is lacking.

The most common problems with erosion/sediment control is improper selection, installation, and maintenance of the management practices involved. This is often due to a lack of adequate training into erosion/sediment control. A crucial recommendation is that a training program for key individuals involved with soil erosion/sediment control be implemented. Some states require designers, contractors, and/or inspectors to be certified to help ensure a certain degree of knowledge in the controls used. Implementation of such a program for the state of Tennessee could help reduce common problems associated with soil erosion/sediment control.

The information in this thesis can help provide the basic guidance necessary to those involved with erosion/sediment control and management. However, typical site conditions may not prevail and site-specific designs may be necessary. Some improvements could be an expansion of the material in this thesis into a more design-oriented format to help designers with more difficult site-specific plans. Another advancement would be to refine the process to an expert system to help with site-specific design.

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APPENDIX

GLOSSARY

The following terms are not all necessarily used within this thesis but are listed due to their frequency of use in soil erosion and sedimentation literature.

Abutment -- The sloping sides of a valley that support the ends of a dam.

Acre-Foot -- A term used to denote a volume of water that will cover one acre to the depth of one foot. One acre-foot contains 325,851 gallons of water.

Aggradation -- The process of building up a surface by deposition. This is a long-term or geologic trend in sedimentation.

Alluvial -- Pertaining to material that is transported and deposited by running water.

Annual Flood -- The highest peak discharge of storm runoff that can be expected in any given year.

Anti-seep Collar -- A device constructed around a pipe or other conduit placed through a dam, dike, or levee for the purpose of reducing seepage losses and piping failures.

Anti-vortex Device -- A device placed at the entrance to a pipe conduit structure such as a drop-inlet spillway or hood-inlet spillway to prevent air from entering the structure when the pipe is flowing full.

Auxiliary Spillway -- See emergency spillway.

Base Flow -- Stream discharge derived from groundwater sources and/or regulated lakes. It fluctuates much less than storm runoff.

Benthic Region -- The bottom of a body of water that supports benthos.

Benthos -- The plant and animal life whose habitat is the bottom of a sea, lake, or river.

Berm -- A narrow shelf or flat area that breaks the continuity of a slope.

Buffer Zone -- A strip of vegetation separating a work site from an environmentally sensitive site. A buffer zone can be used within the work site to help slow velocities of storm runoff and reduce sediment transport.

Channel -- A natural stream or excavated ditch used to convey water.

Channel Stabilization -- Erosion prevention and stabilization of velocity distribution in a channel using riprap, concrete, check dams, energy dissipators, vegetation, and other measures.

Check Dam -- Small dam constructed in a gully or other small watercourse to decrease the stream flow velocity, minimize channel scour, and promote deposition of sediment.

Chute -- A high-velocity open channel for conveying water to a lower level without erosion.

Conduit -- Any structure intended for the conveyance of water.

Conservation -- The protection, improvement, and use of natural resources according to principles that will assure their highest economic or social benefits.

Cubic Foot Per Second -- The rate of fluid flow at which 1 cubic foot of fluid passes a measuring point in one second (abbreviated cfs). Synonymous with second-foot.

Dam -- A barrier to confine or raise water for storage or diversion, to create a hydraulic head, to prevent gully erosion, or to retain soil, rock, or other debris.

Debris Guard -- Screen or grate at the intake of a channel or a drainage or pump structure for the purpose of stopping debris.

Desilting Area -- An area of grass, shrubs, or other vegetation used for inducing deposition of silt and other debris from flowing water; located above a stock tank, pond, field, or other areas needing protection from sediment accumulation.

Detention -- Managing stormwater runoff or sewer flows through temporary holding and controlled release.

Discharge -- 1. Rate of flow, specifically fluid flow. 2. A volume of fluid passing a point per unit time, commonly expressed as cubic feet per second, million gallons per day, gallons per minute, or cubic meters per second.

Diversion -- A channel with a supporting ridge on the lower side constructed across or at the bottom of a slope for the purpose of intercepting surface runoff. See Terrace.

Drainage Area -- The land area which drains water to a given point.

Drop Structure -- A structure for dropping water to a lower level and dissipating its surplus energy; a fall. A drop may be vertical or inclined.

Embankment -- A man-made deposit of soil, rock, or other material used to form an impoundment.

Emergency Spillway -- A channel used to safely convey flood discharges in excess of the capacity of the principal spillway.

Energy Dissipator -- A device used to reduce the energy of flowing water.

Environment -- The sum total of all the external conditions that may act upon an organism or community to influence its development or existence.

Erodible -- Susceptible to erosion.

Erosion -- Detachment and movement of soil or rock fragments by water, wind, ice, or gravity.

Fertilizer -- Any organic or inorganic material of natural or synthetic origin that is added to a soil to supply elements essential to plant growth.

Filter Blanket -- A layer of sand and/or gravel designed to prevent the movement of fine-grained soils.

Filter Fabric -- A woven or nonwoven, water-permeable material generally made of synthetic products such as polypropylene and used in stormwater management and erosion and sediment control applications to trap sediment or prevent the clogging of aggregates by fine soil particles.

Filter Strip -- A long, narrow vegetative planting used to retard or collect sediment for the protection of watercourses, diversions, drainage basins or adjacent properties.

Flocculation -- A process where chemical settling agents form a nucleus that attracts small soil particles.

Flume -- A device constructed to convey water on steep grades; it is lined with erosion-resistant materials.

Gabion -- A galvanized wire basket filled with stone used for structural purposes. They can be fastened together and used for retaining walls, revetments, slope protection, and similar structures.

Grade -- 1. Slope of a road, channel, or natural ground. 2. Any surface prepared for the support of construction such as that for paving or laying a conduit.

Grading -- Any stripping, cutting, filling, stockpiling, or combination thereof which modifies the land surface.

Grassed Waterway -- A natural or constructed waterway, usually broad and shallow, covered with erosion-resistant grasses, used to conduct surface water from an area at reduced rates.

Habitat -- The environment in which the life needs of a plant or animal are supplied.

Hulled Seed -- Seed that has its outer protective covering, or hull, removed to speed germination. It is also called clean seed. Hulled seed is not always scarified (see Scarified Seed).

Hydroseeding -- A method of broadcasting seed and sometimes lime, fertilizer, and mulch together in a mixture of water.

Impoundment -- Generally, an artificial collection or storage of water, as a reservoir, pit, dugout, sump, etc.

Interception Channel -- A channel excavated at the top of an embankment, at the foot of slopes, or at other critical places to intercept surface flow; a catch drain. Synonymous to interception ditch.

Intermittent Stream -- A stream or portion of a stream that flows only in direct response to precipitation. It receives little or no water from springs and no long-continued supply from melting snow or other sources. It is dry for a large part of the year, ordinarily more than 3 months.

Invert -- The lowest point on the inside of a sewer or other conduit.

Land Use Controls -- Methods for regulating the uses to which a given land area may be put, including such things as zoning, subdivision regulation, and floodplain regulation.

Legume -- A member of the botanical family Leguminosae. Some well-known legumes are peas, beans, clovers, and sericea. Most legumes have the ability to take nitrogen from the air for use by plants, and many are important food, forage, and low-maintenance ground cover plants.

Level Spreaders -- A shallow channel excavated at the outlet end of a diversion with a level section for the purpose of diffusing the diversion outflow.

Liming -- The application of lime to land, primarily to reduce soil acidity and to supply calcium for plant growth. Dolomitic limestone supplies both calcium and magnesium. May also improve soil structure, organic matter content, and nitrogen content of the soil

by encouraging the growth of legumes and soil microorganisms. Liming an acid soil to a pH value of about 6.5 is desirable for maintaining a high degree of availability of most of the nutrient elements required by plants.

Loam -- Technically, a soil textural class, but also a term used to designate topsoil, fertile and friable soils, and soils which are easily tilled.

Mean Velocity -- The average velocity of a stream flowing in a channel or conduit at a given cross-section or in a given reach. It is equal to the discharge divided by the cross-sectional area of the reach.

Mulch -- A natural or artificial layer of plant residue or other materials covering the land surface that conserves moisture, holds soil in place, aids in establishing plant cover, and minimizes temperature fluctuations.

Native Species -- A species that is a part of an area's original fauna or flora.

Natural Drainage -- The flow patterns of stormwater runoff over the land in its pre-development state. Elements of natural drainage include overland flow, swales, depressions, rills, gullies, natural watercourses, etc.

Nonpoint Source Pollution -- Pollution that enters a water body from diffuse origins on the watershed and does not result from discernible, confined, or discrete conveyances.

Outfall -- The point, location or structure where waste water or drainage discharges from a sewer to a receiving body of water.

Outlet -- The point of water disposal from a stream, river, lake, tidewater, or artificial drain.

Peak Discharge -- The maximum instantaneous flow from a given storm condition at a specific location.

Perennial Stream -- A stream that maintains water in its channel throughout the year.

Permissible Velocity -- The highest velocity at which water may be carried safely in a channel or other conduit.

pH -- A measure of acidity (pH below 7) or basicity (pH above 7), with pH 7 being neutral and pH 6.5 being a desirable degree of soil acidity. Basicity above pH 7 is rare in eastern U.S. soils.

Photosynthesis -- The basic process of plant life, by which chlorophyll, in the presence of sunlight and nutrients, converts carbon dioxide and water to carbohydrates, with oxygen as a by-product.

Piping -- The progressive development of internal erosion by seepage, appearing downstream as a hole or seam discharging water that contains soil particles.

Point Source -- Any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. (P.L. 92-500, Section 502(14)).

Pollutant -- "Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, chemical wastes, biological materials, radio-active materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water" (P.L. 92-500, Section 502(6)).

Pollution -- The presence in a body of water (or soil or air) of substances of such character and in such quantities that the natural quality of the environment is impaired or rendered harmful to health and life or offensive to the senses.

Principal Spillway -- Generally constructed of permanent material and designed to regulate the normal water level, to provide flood protection, and to reduce the frequency of operation of the emergency spillway.

Reach -- The smallest subdivision of the drainage system consisting of a uniform length of open channel or underground conduit. Also, a

discrete portion of river, stream or creek. For modeling purposes, a reach is somewhat homogeneous in its physical characteristics.

Receiving Stream -- The body of water into which runoff or effluent is discharged.

Recharge -- Replenishment of groundwater reservoirs by infiltration and transmission from the outcrop of an aquifer or from permeable soils.

Retention -- The storage of stormwater to prevent it from entering the storm drain system.

Retention Structure -- A natural or artificial basin that functions similar to a detention structure except that it may maintain a permanent water supply.

Riffles -- Fast sections of a stream where shallow water races over stones and gravel. They usually support a wider variety of bottom organisms than other stream sections.

Riparian Rights -- A principle of common law which requires that any user of waters adjoining or flowing through his lands must so use and protect them that he will enable his neighbor to utilize the same waters undiminished in quantity and undefiled in quality.

Riser -- The inlet portions of a drop inlet spillway that extend vertically from the pipe conduit barrel to the water surface.

Routing -- Storing, regulating, diverting, or otherwise controlling the peak flows of runoff or wastewater through a collection system according to some predetermined plan.

Runoff -- That portion of precipitation that flows from a drainage area on the land surface, in open channels or in stormwater conveyance systems.

Scarified Seed -- Seed that has been treated by scratching the hard seed coat after any hull has been removed. Scarified legume seeds germinate rapidly. Most unscarified seeds lie dormant until the following spring.

Scour -- The clearing and digging action of flowing air or water, especially the downward erosion caused by stream water in sweeping away mud and silt from the outside bank of a curved channel or during a flood.

Sediment -- Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

Sediment Basin -- A depression formed from the construction of a barrier or dam built at a suitable location to retain sediment and debris.

Sediment Discharge -- The quantity of sediment, measured in dry weight or by volume, transported through a stream cross-section in a given time. Sediment discharge consists of both suspended load and bedload.

Significant Rainfall Event -- Any storm producing runoff.

Silt -- A soil consisting of particles between 0.05 and 0.002 millimeter in equivalent diameter. A soil textural class. See Soil Texture.

Silt Loam -- A soil textural class containing a large amount of silt and small quantities of sand and clay. See Soil Texture.

Silty Clay -- A soil textural class containing a relatively large amount of silt, a lesser quantity of clay, and a still smaller quantity of sand. See Soil Texture.

Sod -- 1. Established grass, turf, or sward. 2. Thin rectangles, strips, or pieces of earth and matted grass roots and stems that are transplanted to establish grass cover.

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

Soil Conservation -- Using the soil within the limits of its physical characteristics and protecting it from unalterable limitations of climate and topography.

Soil Profile -- A vertical cross-section of soil layers constitutes the soil profile, which is composed of three major layers designated A, B, and C horizons. The A and B horizons are layers that have modified by weathering, while the C horizon is unaltered by soil-forming processes.

A horizon: The original top layer of soil having the same color and texture throughout its depth. It is usually 10 to 12 inches thick but may range from 2 inches to 2 feet. The A horizon is also referred to as the topsoil or surface soil when erosion has not taken place.

B horizon: The soil layer just below the A horizon that has about the same color and texture throughout its depth. It is usually 10 to 12 inches thick but may range from 4 inches to 8 feet. The B horizon is also referred to as the subsoil.

C horizon: The soil layer just below the B horizon having about the same color and texture throughout its depth. It is quite different from the B horizon. It may be of indefinite thickness. At the beginning of the soil profile development, the C horizon constituted the entire depth, but time, weather, and soil-forming processes have changed the top layers into the A and B horizons described above.

Soil Structure -- The relation of particles or groups of particles which impart to the whole soil a characteristic manner of breaking; some types are crumb structure, block structure, platy structure, and columnar structure.

Soil Texture -- The physical structure or character of soil determined by the relative proportions of the soil separates (sand, silt and clay) of which it is composed.

Spillway -- A passage such as a paved apron or channel for surplus water over or around a dam or similar obstruction. An open or closed channel, or both, used to convey excess water from a

reservoir. It may contain gates, either manually or automatically controlled, to regulate the discharge of excess water.

Stage Construction -- Construction operations protected as they are created. For instance, when a 10-foot change of elevation is reached in cut or fill, the slopes are seeded and mulched; riprap is placed as a ditch or channel is created.

Streambanks -- The usual boundaries, not the flood boundaries, of a stream channel. Right and left banks are named facing downstream

Subcatchment -- A subdivision of a drainage basin (generally determined by topography and pipe network configuration).

Subsoil -- The layer of soil beneath the topsoil. A term sometimes used to indicate soil of low quality for vegetative purposes.

Surface Runoff -- Precipitation that falls onto the surfaces of roofs, streets, ground, etc., and is not absorbed or retained by that surface, but collects and runs off.

Surface Water -- All water the surface of which is exposed to the atmosphere.

Suspended Solids -- Solids either floating or suspended in water, sewage, or other liquid wastes.

Swale -- An elongated depression in the land surface that is at least seasonally wet, is usually heavily vegetated, and is normally without flowing water. Swales conduct stormwater into primary drainage channels and provide some groundwater recharge.

Temporary Protection -- Temporary measures applied to erodible or sediment-producing areas until permanent measures are established.

Terrace -- An embankment or combination of an embankment and channel across a slope to control erosion by diverting or storing surface runoff instead of permitting it to flow uninterrupted down the slope.

Terrace Interval -- Distance measured either vertically or horizontally between corresponding points on two adjacent terraces.

Terrace System -- A series of terraces occupying a slope and discharging runoff into one or more outlet channels.

Topsoil -- 1. A vague term applied to the upper layer of soil. 2. The "plow layer" or upper 6 to 8 inches of soil. 3. The "A" horizons of a soil. 4. A term used to indicate friable, fertile soil applied over other soil to improve conditions for plant growth.

Toxicity -- The characteristic of being poisonous or harmful to plant or animal life; the relative degree or severity of this characteristic.

Trash Rack -- A structural device used to prevent debris from entering a spillway or other hydraulic structure.

Turbidity -- Cloudiness of a liquid, caused by suspended solids; a measure of the suspended solids in a liquid.

Uniform Flow -- A state of steady flow when the mean velocity and cross-sectional area remain constant in all sections of a reach.

Vegetative Protection -- Stabilization of erosive or sediment-producing areas by covering the soil with:

(a) Permanent seeding, producing long-term vegetative cover;
(b) Short-term seeding, producing temporary vegetative cover; and
(c) Sodding, producing areas covered with a turf of perennial sod forming grass.

Water Quality -- A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

Water Resources -- The supply of groundwater and surface water in a given area.

Watershed -- The area contained within a divide above a specified point on a stream and the source of the stormwater runoff; oftentimes called drainage areas, drainage basin, or a catchment area.

Watershed Management -- Use, regulation, and treatment of water and land resources of a watershed to accomplish stated objectives.

VITA

Telena Dianna Moore was born in Baltimore, Maryland, on June 15, 1962. Her parents made a permanent move to Johnson City, Tennessee, shortly after her birth. She graduated from Science Hill High School in May 1980 and became a licensed cosmetologist in December 1983. Ms. Moore moved to Knoxville, Tennessee in 1984 to attend The University of Tennessee where she graduated with a Bachelor of Science degree in Civil Engineering in May 1991.

Ms. Moore put herself through college working as a cosmetologist until February 1991 when she began employment at The University of Tennessee, Knoxville. She taught the laboratory portion of the hydraulics course in Civil Engineering and participated in research into soil erosion and sediment control. The teaching position was from May 1991 to May 1992 and included lecture preparation along with testing of devices such as weirs, venturi meters, and culverts. The research position was from February 1991 to April 1992 and resulted in co-authorship of a manual and short training course for inspector personal on the proper design, placement, maintenance, and problems associated with commonly used soil erosion and sediment control procedures. The research helped provide the basis for her thesis.

Ms. Moore is presently (July 1992) employed at Oak Ridge National Laboratory (ORNL), where she is involved in processing precipitation data and participating with sediment transport modeling. She plans to continue her work at ORNL upon completion of the Master of Science degree in Environmental Engineering.