TDOT DESIGN DIVISION

DRAINAGE MANUAL

CHAPTER X
EROSION PREVENTION AND SEDIMENT CONTROL

CHAPTER 10 – EROSION PREVENTION AND SEDIMENT CONTROL

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SECTION 10.01 – INTRODUCTION

This chapter presents the procedures, methods, and available measures to be used by the Tennessee Department of Transportation (TDOT) for the proper design of an effective Erosion Prevention and Sediment Control (EPSC) plan. The information is presented with the assumption that the designer is generally familiar with road and bridge design and understands the basic principles of hydrology, hydraulics, and stormwater runoff typically encountered on a roadway project.

The use of the approved devices found in the EC-series Standard Drawings is required for an effective design. While the guidance provided in this chapter should be used for the design of an EPSC plan, it is not all encompassing. This chapter does not discuss hydrologic methods for determining stormwater runoff used in the design of a project's erosion prevention and sediment control plan. Details on these methods are provided in Chapter 4 of this Manual.

With continued development and increased construction, the issue of erosion has become more pronounced in the United States. At first glance, one small construction project would not seem to cause much erosion damage. However, detailed studies conducted since the 1930's have shown a significant correlation between construction projects and erosion damage. This damage often does not occur at the actual site of construction, but rather downstream where sediment can clog storm sewer lines or cause damage to waterways. The damage can be costly, not only in terms of monetary value, but also in terms of adverse impacts on the environment such as harm to aquatic life in waterways that provide recreation and food.

The primary function of an EPSC plan is to reduce the physical, chemical, biological and economic damage which can be caused by pollution due to sediments which have been eroded from a construction site. TDOT construction projects can vary in scope from very large projects which result in extensive areas of land disturbance to much smaller projects which may disturb only 1 to 2 acres. Regardless of the project size, minimizing erosion and ensuring that any eroded sediments are retained on site play an important role in protecting Tennessee's natural environment. The goal of this chapter is to assist the designer in formulating EPSC plans which will achieve their intended purpose at a reasonable cost. Towards that end, this Chapter will provide information on:

- Types and causes of erosion and sedimentation
- Methods of calculating potential sediment loss
- Best Management Practices (BMPs) for controlling erosion and sedimentation
- The development of an effective EPSC plan
- EPSC plan requirements for TDOT projects

SECTION 10.02 – DOCUMENTATION PROCEDURES

The designer will be responsible for documenting the computations and design decisions made pertaining to the EPSC plans for a project. In general, the documentation should be sufficient to answer any reasonable question that may be raised during construction regarding the proposed plan and should be organized by EPSC plan stage.

The documentation should be stored in a project folder and should include a discussion of any unusual features or conditions within the project. Further, any assumptions and design decisions made to accommodate those special conditions should be clearly and concisely documented. Where EPSC measures are designed using procedures other than normal or generally accepted engineering procedures, a summary detailing the design basis should be included in the project folder. Where innovative or alternative BMPs are specified, records of their performance testing showing equivalent or superior performance to currently accepted BMPs shall be retained in the project folder. Additionally, any environmental or other special considerations which may have influenced the design should be documented. These include any requirements from all applicable permits and/or environmental documents.

If computations are performed by hand, copies of the completed worksheets should be included in the project file. If computer generated solutions are employed, hard copies of the outputs should be included in the project file. Each computation sheet or computer output should be clearly labeled with the project description, a description of the type of computation, project station, the date, and the initials of the designer. When computerized computations are employed, this information should be included along with the input data used for the program. Otherwise, it will be necessary to label output files by hand.

For in-house projects, documentation of the EPSC plan will be maintained with the project files. For consultant designed projects, all documentation will be maintained by the consultant and will be made available to the Department upon request. Computations and other records pertaining to the preparation of the EPSC plan should be retained for a period of at least one year following the completion of construction, or in accordance with the current records retention policy, whichever is longer.

SECTION 10.03 – FUNDAMENTALS OF EROSION AND SEDIMENT LOSS

10.03.1 DEFINITIONS

Erosion is a natural process in which a ground surface is worn away due to the detachment of soil particles by external forces such as rain or wind. These eroded materials, known as sediments, can then be transported by, or suspended in, flowing water. When the velocity of the water is reduced, gravitational deposition of the sediments occurs in a process known as sedimentation. These sediments can interfere with the natural habitat provided by a stream or result in a loss of capacity in a stormwater conveyance system, such as a storm sewer.

Erosion can be greatly accelerated, as compared to its natural occurrence, during a project such as the construction of a roadway. The use of grading equipment, removal of existing vegetation and exposure of bare soil create conditions in which erosion may occur much more easily. It is estimated that accelerated erosion from construction sites can produce from 20 to 200 tons per acre per year of sediment as opposed to cropland erosion which typically produces from 2 to 20 tons per acre per year.

Sedimentation is the gravitational deposition of transported material being transported by water or wind. Sedimentation is a natural process that occurs when the velocity of the water in which soil particles are suspended is sufficiently slowed for a long enough period of time to allow the particles to “drop out” of suspension. The settling rate is dependent on the soil particle size. Heavier particles, such as gravel and sand, will drop out more rapidly than fine particles such as silt and clay. Due to their very small size, sedimentation for clay particles can be quite slow, resulting in turbidity problems.

The primary purpose of the EPSC plan is to minimize the potential for pollution which can be caused by excessive amounts of sediment leaving a construction site. A properly designed erosion prevention and sediment control plan will not only reduce the amount of erosion which may occur, but will also help to retain eroded sediments on the site. Effective erosion prevention and sediment control practices on a construction site can greatly reduce undesirable environmental impacts and costs beyond the project outfalls. These impacts, and their associated costs, are often obvious; but sometimes can be subtle and difficult to quantify, such as loss of aesthetic values to Exceptional Tennessee Waters or the loss of recreational opportunities on streams or lakes.

10.03.1.1 EROSION PREVENTION

Erosion is a natural process that occurs over time. Erosion prevention is the process of applying planned measures to slow the increased erosion or minimize the dislodging of sediment which can result from man-made changes to the landscape. It begins with predicting those locations throughout the construction project which will have a higher potential for erosion due to the construction activity. Erosion prevention then entails taking proper precautions at these locations to eliminate or reduce the potential for soil loss. This is accomplished by providing vegetation or other measures which serve to shield the soil, hold soil particles together, or reduce stormwater runoff velocities. Careful consideration of the site topography, soil types, climate, and vegetation can greatly enhance the effectiveness of a proposed erosion prevention plan. However, since erosion is a natural occurrence, not all erosion can be prevented; therefore, the secondary treatment mechanism of sediment control should normally be considered.

10.03.1.2 SEDIMENT CONTROL

Sedimentation occurs as eroded materials are transported through a construction site by flowing water and then are re-deposited when the velocity of the water slows. The purpose of sediment control is to ensure that eroded sediments do not leave the construction site. This is accomplished by directing sediment laden stormwater runoff to specific locations where sedimentation can occur. In this way, the water flowing from the site will be relatively sediment-free so that off-site pollution due to sedimentation will be minimized.

In one sense, the best sediment control measure is to ensure that on-site erosion does not occur in the first place. However, since this is not practical, planned sediment control measures are installed on the project site to collect eroded sediments and retain them on site. Thus, sediment control measures should be considered as secondary to erosion prevention. Although sediment control measures are required for most projects, they essentially serve as a “back-up” for the erosion prevention measures. The cost to maintain and repair the sediment control measures will be directly tied to the efficiency of the erosion prevention measures. If construction site erosion can be minimized, the task of controlling sediment will be simplified.

10.03.2 TYPES OF EROSION

Erosion is the naturally occurring process by which a land surface is worn away by the action of wind, water, ice, gravity or any combination of these forces. This section describes the types of water-generated erosion that may occur on construction projects and the conditions that cause each type of erosion. Water causes erosion by breaking soil particles loose and transporting them from their original location. This process begins with raindrop erosion, and, as water begins to flow, is followed by sheet erosion (also called inter-rill erosion), rill erosion, gully erosion, and finally channel erosion. See Figure 10-1 for a schematic of this process.

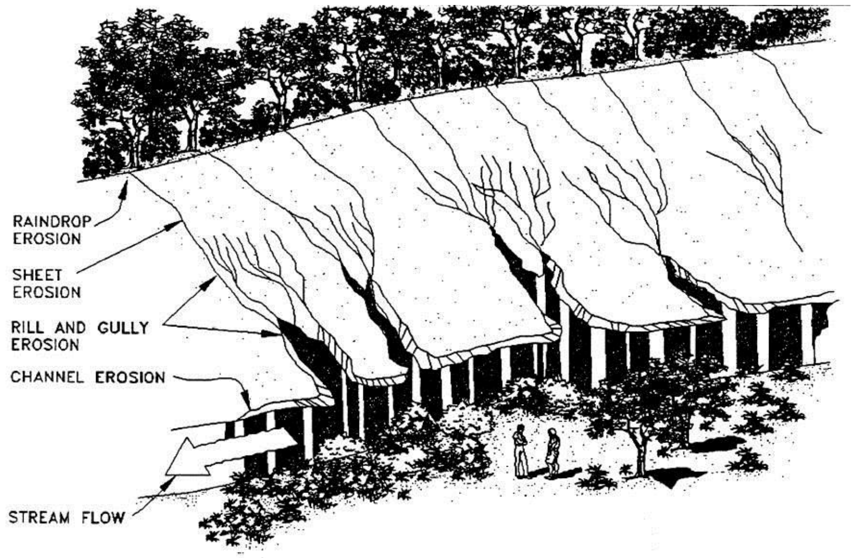


Figure 10-1
Types of Erosion
Reference: Michigan Soil Erosion and Sedimentation Guidebook (1975)

Several factors influence the rate and magnitude of soil erosion by water. These factors include: the rainfall intensity, soil characteristics, topography, and surface cover conditions. Section 10.03.4 will discuss these contributing factors in detail and will describe how they influence the erosion process.

10.03.2.1 RAINDROP EROSION

Raindrop erosion, often referred to as splash erosion, is the first effect a rain event has on the soil. It results from the bombardment of the soil surface by raindrops and is considered the primary cause of soil detachment and soil disintegration. Raindrop erosion occurs where vegetative cover is either absent or of poor quality. When a raindrop impacts bare earth, the soil particles are dislodged and may splash into the air. These detached particles are then vulnerable to the movement of overland water flow. Additionally, resettled sediment typically blocks natural soil pores creating a crust on the surface which lowers the infiltration of stormwater. Soil movement by raindrop erosion is typically greatest and most noticeable during short duration, high intensity thunderstorms. Figure 10-2 shows the beginning of the erosion process with the impact of a single raindrop.

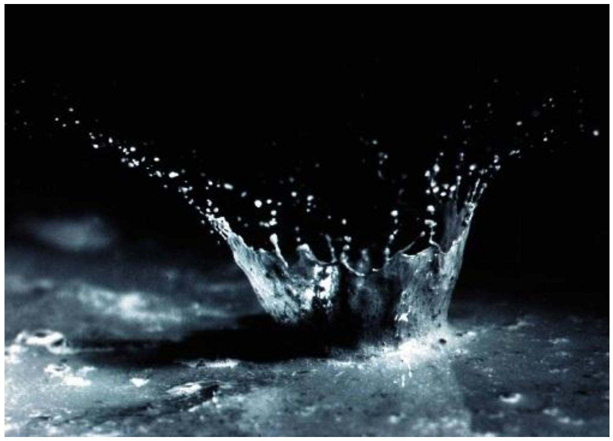


Figure 10-2
The Beginning of the Erosion Process
Reference: USDA, NRCS (1999)

The primary method of preventing raindrop erosion is to stabilize the soil with temporary or permanent vegetation as soon as possible after land disturbing activities. During the period when vegetation is becoming established, temporary cover can be maintained with mulch or erosion control blankets. Maintaining this ground cover is important to prevent the detachment of soil and the initiation of sheet erosion.

10.03.2.2 SHEET EROSION (INTERRILL EROSION)

Sheet erosion is the erosion caused by the flow of water as it runs off the land in a shallow sheet. These very shallow moving sheets of water normally in laminar or a subcritical flow regime are seldom the detaching agent, but they can transport soil particles which have been detached by raindrop impact and splash. Shallow surface flow rarely moves as a uniform sheet for more than a few feet on land surfaces before concentrating into irregular surface contours. This type of erosion can occur at the uppermost end of the erosion process or between rills. Thus, it is often referred to as interrill erosion.

The most effective method of preventing sheet erosion is to maintain a good cover of vegetation or mulch on a surface to prevent the dislodging of soil particles resulting from raindrop impacts. Additionally, roughening a slope surface and diverting flow away from it can be effective techniques for minimizing the potential for sheet erosion.

Figure 10-3
Sheet and Rill Erosion
Reference: USDA, NRCS (1999)

10.03.2.3 RILL EROSION

Rill erosion is the erosion which develops as sheet surface flow begins to concentrate in the low spots of irregular surface contours. As the flow type changes from sheet flow to deeper shallow concentrated flow in these low areas, the velocity and turbulence increase. The energy of this concentrated flow is able to both detach and transport soil materials and this action begins to cut small channels into the soil. Rills are small but well defined channels which are at most, only a few inches in depth. They are easily leveled out by tillage equipment or by other surface treatments.

The damage from rill erosion should be repaired immediately to prevent further damage. Rill erosion may be prevented by stabilizing slopes with vegetation, mulch, erosion control blankets, roughening the surface, soil binders, tackifiers, or by diverting surface sheet flow away from the slope.

10.03.2.4 GULLY EROSION

Gully erosion occurs as the flow in rills comes together into larger and deeper channels. The major difference between gully and rill erosion is a matter of magnitude. Gully erosion results when small erosion problems, such as rill erosion, are not corrected in time. Gullies are typically too large to be repaired with conventional tillage equipment and usually require heavy equipment and special techniques for stabilization.

Similar to preventing rill erosion, preventing gully erosion involves stabilizing the slopes and diverting concentrated flow. Damage from gully erosion should be repaired immediately.

Figure 10-4
Rill Erosion on an Unprotected Cut Slope
Location: SR-385, Shelby County, TN (2004)

Figure 10-5
Gully Erosion on Fill Slope
Location: SR-169, Knox County, TN (2004)

10.03.2.5 CHANNEL EROSION

Channel erosion can occur as the volume and velocity of a concentrated inflow wears away the bed and bank of a well-defined channel or side ditch. Once a bank washes away, unstable conditions along the edges of the stream, river, or other channel can occur. The aesthetic attraction of many streams, lakes and reservoirs used for swimming, boating, fishing and other water-related recreational activities may be impaired or destroyed by channel erosion.

Channel erosion can be prevented by establishing a vegetative and/or an undisturbed buffer zone along an existing waterway and by providing appropriate stabilization measures where a concentrated flow enters a waterway. It may also be prevented by providing stormwater detention to offset any increase in runoff which may occur as a result of a project.

Figure 10-6
Channel Erosion Resulting from Excessive Flow and Velocity
Location: SR-169, Knox County, TN (2004)

10.03.3 TYPES OF SEDIMENT

Sediment consists of debris and/or soil particles that have been collected by stormwater runoff. Sedimentation is the gravitational deposition of transported material in standing or flowing water. Normally, runoff builds up rapidly to a peak and then diminishes more slowly. Large amounts of sediment can be produced by erosion and then transported during the time that higher flows are building up. As the flow diminishes, heavier particles like gravel and sand will settle out more rapidly and are thus deposited first. Fine particles, such as silts and clays, settle out much more slowly and may even remain suspended. The following sections compare the characteristics of bedload sediment and suspended sediment.

10.03.3.1 BEDLOAD

Bedload consists of heavier and coarser-grained materials that are transported in the lower layer of stream flow by rolling or bouncing. Usually these sediments are the first to settle as the flow begins to recede following a rainfall event. This material is not usually re-suspended until the next large storm event occurs.

Coarser-grained materials released from a construction site can blanket a stream bottom and suppress the aquatic life which may be found there. When currents are strong enough to move the bedload sediment, the abrasive action of these materials can potentially accelerate channel erosion and further affect aquatic life. Additional discussion on bedload is presented in Chapter 11 of this Manual.

10.03.3.2 SUSPENDED SEDIMENT

Suspended sediments are usually composed of fine sand, clay, silt, or any other material not heavy enough to settle with the bedload sediments. The sedimentation process for these materials takes place where the flow velocity slows and the water is less turbulent. The deposition of these materials can require several hours, or even days, and this sediment is more likely to be re-suspended when the next storm event occurs.

The introduction into a stream of large amounts fine sediments from a construction site can result in both increased sedimentation on the stream bottom and increased turbidity. This can degrade the habitat for a variety of bottom-dwelling organisms. In larger streams, this can also affect the ability of fish to feed and to reproduce.

10.03.4 FACTORS CONTRIBUTING TO EROSION AND SEDIMENTATION

The erosion potential of any area is determined by four principal factors: soil characteristics, topography, surface cover conditions, and rainfall intensity. These factors can be illustrated as shown in Figure 10-7. The first three of these factors are constant with respect to time until altered by construction activity. Although each of these factors is discussed separately in the following sections, they are interrelated in determining erosion potential. Understanding these factors can help the designer identify potential erosion and sedimentation concerns and adapt the EPSC plan to best accommodate the conditions at a specific project site.

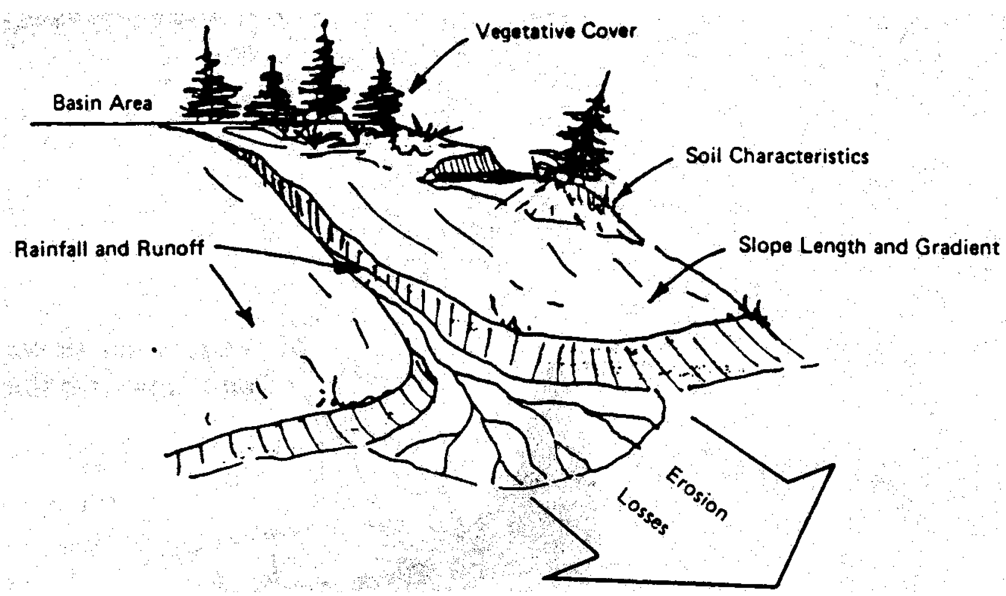


Figure 10-7
Contributing Factors to Erosion and Sedimentation
Reference: SWMM for Western Washington, WA Dept. of Ecology (2005)

10.03.4.1 SOIL CHARACTERISTICS

The characteristics of a given soil type influence its potential for erosion in two different ways. First, the mechanical properties of a soil determine its resistance to detachment and being carried away by falling rain and the ensuing runoff. Second, those properties which affect the infiltration capacity of a soil determine the quantity of runoff which will be generated by a given rainfall event. Higher runoff rates, in turn, increase the potential for erosion. Thus, the following factors are important in determining soil erodibility:

- Soil texture (particle size and gradation)
- Percentage of organic content
- Soil structure
- Soil permeability

Soils containing high percentages of fine sands and silt are normally the most erodible. As the clay and organic matter content of these soils increases, the erodibility decreases. Clays act as a binder to soil particles, thus reducing erodibility. However, while clays have tendency to resist erosion, once eroded, they are easily transported by water and settle out very slowly. Soils high in organic matter have a more stable structure which improves their permeability. Such soils resist detachment resulting from raindrop impacts and normally have higher infiltration rates. Clear, well-drained and well-graded gravel and gravel-sand mixtures are usually the least erodible soils. Their high infiltration rates delay the occurrence of runoff and reduce its quantity.

The designer should obtain and review the available soils information for his or her project prior to beginning the design of the EPSC plan. For many projects, this information will be provided by the Geotechnical Section of the Materials and Tests Division. If a project specific soils report is unavailable, the designer can normally obtain the necessary information from NRCS County Soil Surveys and/or site reconnaissance.

10.03.4.2 TOPOGRAPHY

The size, shape, and slope characteristics of a watershed influence the amount and the rate of runoff it will produce. As both the length and gradient of a slope increases, the rate of runoff increases, and the potential for erosion will increase. Additionally, slope orientation (the direction the slope is facing) may be a factor in determining erosion potential. For example, a slope that faces south and contains sandy soils may have such poor growing conditions that vegetative cover will be difficult to establish.

The topography at a construction site, including existing, interim, and final grading, is a significant factor to be considered in selecting the appropriate BMP to be used at a particular location on a TDOT project site. Each site has unique dimensions and characteristics which may provide both opportunities for, and limitations on, the use of a particular prevention or control measure. Additional information regarding proposed topographic and site grading considerations when designing a project can be found in Section 10.04.5.

10.03.4.3 SURFACE COVER CONDITION

Vegetative cover helps control the potential for erosion by:

- shielding the soil surface from raindrops
- providing root systems which hold soil particles in place
- maintaining the soil's capacity to absorb water
- slowing the velocity of runoff, thereby permitting greater infiltration
- removing subsurface water between rainfall events through evapotranspiration

Soil erosion and sedimentation can be significantly reduced by limiting the premature or unnecessary removal of existing vegetation and by removing it in stages. Minimizing the area of bare soils and the duration of their exposure to rainfall events will provide a significant benefit in decreasing erosion. Special consideration should be given to the maintenance of existing vegetative cover on areas of high erosion potential, such as moderately to highly erodible soils, steep slopes (35% or greater), drainage ways, and areas adjacent to stream banks.

10.03.4.4 RAINFALL INTENSITY

Rainfall intensity is generally predictable by season, historical records, and probability of occurrence. While it is not possible to predict a rainfall event with absolute certainty, many of the negative impacts of construction site runoff can be minimized by planning appropriate seasonal construction activities and using properly selected and designed BMPs.

The frequency, intensity, and duration of rainfall in any given storm event are fundamental factors in determining the amount of runoff generated in a given area. As the volume and velocity of runoff increases, its ability to detach and transport soil particles also increases. Erosion risks are higher when storms are frequent, intense, or of long duration. Seasonal changes in temperature, as well as variations in rainfall, help to define the period of the year when erosion risks are greatest. When precipitation falls as snow, no erosion will take place. Additionally, frozen soils are relatively erosion resistant. However, when the temperature rises, melting snow adds to runoff, and erosion potential may be increased. Additionally, soils with high moisture content are subject to uplift by freezing action and are usually easily eroded upon thawing.

10.03.5 CONSTRUCTION SITE RUNOFF

The stormwater runoff characteristics of a site can be significantly altered as a result of a highway construction project. Not only can temporary changes occur during the construction process, but alterations to the land use can cause permanent changes as well. During construction, runoff rates can be significantly increased due to the removal of existing vegetation, compaction of soil by construction equipment, the addition of paved areas, and the channeling of flows in ditches and storm sewers. Thus, a storm which generates a given quantity of rainfall could generate significantly more runoff during a construction project than it would have before the project started. At the same time, the construction process exposes previously covered soil to direct impact from rain drops and other erosion-causing mechanisms. The combination of these factors can result in a greatly increased sediment load in site runoff, as compared to the pre-construction condition.

EPSC measures should be used to minimize the quantity of sediment released from the site during construction. Typically, increased flow rates experienced during construction are not directly addressed due to the fact that the duration of construction is relatively short as compared to the return period of a major flood event. However, a number of sediment control measures, especially ditch checks, sediment traps, and sediment basins, can indirectly help to mitigate these increased flow rates.

After construction has been completed, runoff rates may be higher as compared to the pre-construction condition due to added impervious surfaces or channelization of runoff. It may also contain grease, oils, or other materials related to the use and maintenance of the highway facility. The need to address either stormwater quantity or quality after construction will be determined on a case-by-case basis by the Design Manager. The design of detention basins primarily for quantity issues is discussed in Chapter 8 of this Manual.

10.03.5.1 EFFECTS OF LAND DISTURBANCE OVER TIME

The reshaping of land for development alters the land cover and soil in many ways. During a construction project, existing vegetation is reduced or removed, excavations are made, topography is changed, soil is stockpiled, and soil properties are altered. All of these changes can expose disturbed soils to precipitation and to surface storm runoff, thus greatly increasing the amount of erosion which may occur. This erosion can increase the cost to landscape and maintain a site, especially where the topsoil has been lost. Further, sediment is difficult and expensive to remove from on-site drainage facilities, such as storm sewers and culverts.

Where left unchecked by erosion prevention and sediment control measures, excessive sediment can be released from a construction site and cause a variety of off-site environmental impacts. Some of these impacts are as follows:

Water quality may be impaired by sediment from construction sites. Excessive sediment release from a construction site can transfer nutrients and other pollutants to downstream lakes and rivers, degrading habitats and spawning areas for aquatic organisms. This sediment can adversely affect water clarity, thus reducing sunlight penetration and limiting photosynthesis by aquatic plants.

Excessive sediment from construction sites may cause loss of flood conveyance and storage. Sediments released from construction sites can collect in storm sewers, ditches, streams, detention basins, or wetlands. In extreme cases, this accumulated sediment can cause drainage and flooding problems. Thus, any accumulated sediment should be removed to maintain adequate flow capacity and storage of stormwater.

Erosion and sediment may cause safety and nuisance problems. Sediment conveyed onto roadways either by direct runoff or by tracking from construction vehicles may become a traffic safety hazard. Additionally, dust generated from soil on uncontrolled construction sites can be a nuisance for adjacent property owners.

Natural areas may be degraded. Long-term sediment accumulation from unprotected construction sites can adversely impact natural environmental features such as streams or wetlands. Sediments alter the characteristics of these areas by covering the existing soils. For example, a rock and gravel stream bottom can be clogged by sand and clay deposits. Further, existing plants and indigenous seed banks can be covered. Site erosion and subsequent material transport can also bring in plant seeds from other areas, which then compete with the original species.

In general, the sediment released from unprotected construction sites can have significant environmental and economic impacts. It is because of the potential for these and other impacts, and the value to the public of the potentially affected resource, that erosion prevention and sediment control measures will be required on most TDOT construction projects.

10.03.5.2 METHODS FOR COMPUTING RUNOFF

Computing stormwater runoff is a very important step in designing many types of erosion prevention and sediment control measures, but is often overlooked. Most BMPs used by TDOT are designed using a 5-year, 24-hour storm event, unless they are intended to be a part of the permanent facility (although in some cases a 2-year, 24-hour design may be used). Design flow rates for measures where the drainage area is greater than 100 acres may be determined by the TR-55 or the USGS Rural Regression Equations. Design flow rates for small drainage areas may be determined using the Rational Method. These methods of computing storm runoff are discussed in Chapter 4, along with approved software systems which may be used as alternate methods. In addition, the TDOT standard erosion prevention and sediment control drawings offer a few tools to help simplify the determination of the design flow rate.

10.03.6 PREDICTING AND QUANTIFYING SOIL LOSS

This section presents methods for predicting and quantifying soil loss. Additionally, some generally accepted practices and/or “rules of thumb” used for estimating soil loss quantities are also included. While most of the BMPs contained in the EC-series Standard Drawings have been designed, and are to be used, without the need to calculate expected sediment loads, some situations may arise during the development of a project where the designer may be required to calculate the expected soil loss. Such instances may include designing a sediment basin for a disturbed watershed greater than 5 acres draining to one project outfall, or in a case where off-site “run-on” sediment loading is of concern.

10.03.6.1 GENERALLY ACCEPTED QUANTITIES

In general, the amount of erosion which may occur on a site is variable and may be affected by factors such as rainfall intensity, soil characteristics, topography and surface cover conditions. Thus, estimates of “typical” erosion rates for different situations can vary widely. Table 10-1 provides ranges of erosion rates which may occur for various types of land use. This table is not a substitute for more rigorous means of computing soil loss rates, as described in the following section; however, it may serve as a guide to evaluate the results of those computations or to provide the designer with a “rough” estimate during the early stages of project design.

10.03.6.2 RUSLE THEORY AND COMPUTATIONS

The science of quantifying soil loss on a site has evolved considerably over the past 50 years. The Universal Soil Loss Equation (USLE) was developed in the late 1950’s by USDA Agricultural Research Service scientists W. Wischneier and D. Smith. This equation was the culmination of a large number of research projects across the country. The USLE is limited in that it predicts annual erosion, not storm or event generated soil loss. The USLE was the most widely accepted and utilized soil loss equation until the publication of the Revised Universal Soil Loss Equation (RUSLE) in the mid 1990’s.

Land Use	Approximate Erosion Rates (Tons / Acre / Year)
Forested	1 (or less)
Pasture Land	1.5
Agricultural, no-till	2 – 6
Agricultural, conventional tillage	6 – 20
Construction Site	20 – 200

Table 10-1
Generally Accepted Yearly Erosion Rates
Reference: USDA, TDEC, University of Kentucky, U.S. EPA

The RUSLE can estimate long term annual soil loss, but does not apply to a specific year or a specific storm. In addition, it is used to predict the average annual soil loss caused by sheet and rill erosion but does not predict erosion in channels. The equation also does not estimate sediment yield. It computes only the quantity of soil eroded on a site, not the quantity of sediment leaving a site. That is, the method does not take into account sediments which may be re-deposited prior to leaving the site.

When using the RUSLE equation to determine soil loss, it should be noted that the C and P factors have not yet been calibrated for use in roadway construction applications. The conservation practice factor, P, does not allow for evaluating combinations of practices in a way that will allow optimization of design. However, the RUSLE equation is currently the most readily-available tool that is simple to use and relies on commonly available data.

The RUSLE utilizes the same formula and methods as the USLE model. The major improvements to the equation consist of updated, expanded, and improved methods for estimating the equation parameters. The improvements have greatly expanded the applicability and accuracy of the equation. The RUSLE is discussed in-depth in the USDA Agriculture Handbook Number 703, *Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE)*.

The RUSLE is written as:

$$A = (R)(K)(LS)(C)(P) \tag{10-1}$$

Where:

A = average annual soil loss, tons per acre per year
R = rainfall-runoff erosivity factor, hundreds of foot-ton (force)-inch per acre-hour-year
K = soil erodibility factor, ton-acre-hour per hundreds of acre-foot-ton (force)-inch
LS = topographic factor, dimensionless
L = slope length factor, dimensionless
S = slope steepness factor, dimensionless
C = cover management factor, dimensionless
P = support practice factor, dimensionless

The rainfall runoff erosivity factor, R, is a measure of the ability of the rainfall which occurs in an average year to erode soil. This factor combines rainfall kinetic energy, E, which accounts for the size and terminal velocity of the raindrops, with the rainfall intensity, I, which would occur in a maximum 30-minute storm. These two factors are multiplied together (EI) and then summed for the total number of rainfall events in a normal year. Table 10A-1 in the Appendix may be used to determine an erosivity value for any location in Tennessee.

The soil erodibility factor, K, represents the susceptibility of a soil or surface material to erode due to raindrop impact or surface runoff. In other words, K gauges the amount of erosion which would occur in a given soil for a given amount of energy applied by rainfall or other factors. The K factor can be affected by soil texture, soil structure, organic matter content, permeability, and freeze/thaw conditions. In general, greater values of soil erodibility factor reflect more easily eroded soils. Table 10-2 shows K factors for several types of soil.

Soil Type	K
silt loam, silty clay loam, very fine sandy loam	0.37
clay, clay loam, loam, silty clay	0.32
fine sandy loam, loamy very fine sand, sandy loam	0.24
loamy fine sand, loamy sand	0.17
sand	0.15

Table 10-2
K Factors for RUSLE Equation
Reference: USDA, Agricultural Handbook No. 703 (1996)

The slope length factor, L, accounts for the length of a slope from its top to the point where concentrated flow begins (See Section 10.03.2). In general, longer slopes have a greater potential for erosion. The determination of L should be based on a careful evaluation of the horizontal distance along the slope. Ideally, the slope length should be determined by inspection of the site, since it is often difficult to determine from topographic mapping where concentrated flow begins. Topographic mapping may be used to determine the slope length; although caution should be used to not over-estimate it. Slope lengths usually do not exceed 400 feet and a length longer than 1000 feet should not be used for the RUSLE method.

The slope steepness factor, S, reflects the gradient of a slope. As the gradient increases, more energy is available for scouring and transporting soil. The gradient of a slope is usually determined by measuring the distance between contours on the topographic mapping for a site, provided that the contour interval is no greater than 2 feet.

The slope length and steepness factors, L and S, are not directly entered into the RUSLE. Rather, they are combined into the topographic factor, LS, which is then entered into the equation. Once the slope length and gradient have been determined, Table 10A-2 in the Appendix may be used to determine the LS factor for a uniform slope. The topographic factor is also affected by the amount of erosion which occurs in between rills as compared to erosion which occurs in the rills themselves. This ratio, called the rill to inter-rill ratio, and is determined by the land use on the site. Table 10A-2 provides values for the topographic factor which are appropriate for construction sites. The USDA's *Agricultural Handbook Number 703* includes tables which may be applied to areas in various types of agricultural use.

Where a slope is not uniform, the effective topographic factor, LS, may be determined by dividing the slope into segments of more or less uniform slope. However, because erosion on each segment is affected by runoff from the segment above it, the effective topographic factor will not equal the average of the values for each segment. Further, the effective topographic factor will be affected by whether the shape of the slope is convex, concave or irregular. The designer should refer to Agricultural Handbook Number 703 for detailed information on these computations.

The cover management factor, C, gauges the effect of varying cropping and land management practices on erosion rates. It is the most significant factor in erosion prediction as well as the most complicated. As applied in the RUSLE, this factor accounts for prior land use, type of vegetative cover, quantity of residue on the surface, surface roughness and soil moisture. It is computed as the ratio of the expected soil loss for a specific set of circumstances to the soil loss expected on a test plot consisting of tilled soil with no cover.

When estimating soil loss on construction sites, an average value for the cover management factor should be computed. A value of "1" is recommended for any exposed soils, while values for other conditions are provided in Table 10-3. Based on the proposed construction staging plan, the percentage of the site in each cover condition should be estimated to compute a weighted average C factor based on the proportions of the various cover types on the site. Where the cover conditions will vary during the project, it is recommended that the stage during which the most soil is exposed be used to compute the average.

As applied in agriculture, the support practice factor, P, accounts for soil tillage practices which help reduce erosion potential. These practices could include measures such as terracing or tilling along the contour, which affect erosion by modifying the grade or direction flow. The support practice factor represents a ratio of the erosion potential of a given tillage practice to the erosion potential of a plot tilled up and down along the slope. When applied to a construction site, P may be used to represent surface roughening used as an erosion prevention measure (see Section 10.08.1) or to represent the lack of any such treatment. Table 10-4 provides values for P based on various conditions which may be encountered on a construction site. It may be noted that these values do not vary greatly from a value of 1. The designer should bear in mind that this factor considers only the condition of the soil surface, while the cover management factor, C is used to account for vegetative cover. For example, a soil surface which has been roughened to establish plantings for seeding and then mulched with hay at a rate of 1.0 tons/acre would be assigned a P value of 1.0, as shown in Table 10-4, and a C value of 0.13, as shown in Table 10-3.

Type of Cover	Application Rate (tons per Acre)	C
None (Uncultivated Ground)		1
Temporary Seeding (90 percent stand):		
Ryegrass (perennial type)		0.05
Ryegrass (annuals)		0.10
Small grain		0.05
Millet or Sudan grass		0.05
Field brome grass		0.03
Permanent Seeding (90 percent stand):		0.01
Sod (laid immediately)		0.01
Mulch:		
Hay	0.50	0.25
Hay	1.00	0.13
Hay	1.50	0.07
Hay	2.00	0.02
Small grain straw	2.00	0.02
Wood chips	6.00	0.06
Wood cellulose	1.75	0.10

Table 10-3
C-Factor for Construction Sites
Reference: USDA, NRCS, Field Office Technical Guide

The RUSLE has been developed specifically as a tool to estimate soil erosion rates on agricultural lands. Thus, appropriate engineering judgment should be used when applying the method to construction sites. The topographic factor, LS, should be calculated to fit the project site. However, where slope gradients or lengths vary across the length of a project, it may be possible to compute LS based on a length and gradient which represent average conditions on the site. Otherwise, the project can be broken in to sections in which the slope lengths and gradients are fairly consistent. The RUSLE would then be applied to each section individually and the results for each segment added to determine the total. The cover management factor, C, and the support practice factor, P, may be averaged based on the proportions of the site which will be covered by each of the various practices. If it is available, the construction staging plan may be used to determine these averages, based on sound engineering judgment.

Surface Condition with No Cover	P[1]
Compact and smooth, scraped with bulldozer or scraper up and downhill	1.3
Same condition, except raked with bulldozer root rake up and downhill	1.2
Compact and smooth, scraped with bulldozer or scraper across the slope	1.2
Same condition, except raked with bulldozer root rake across the slope	0.9
Loose, as a disked plow layer	1.0
Rough, irregular surface equipment tracks in all directions	0.9
Loose with rough surface greater than 12 inches depth	0.8
Loose with smooth surface greater than 12 inches depth	0.9

Table 10-4
P-Factor for Surface Condition at Construction Sites
[1] Values based on estimates only
Reference: USDA, NRCS, Field Office Technical Guide

SECTION 10.04 – CONTROL MEASURES AND PRACTICES

10.04.1 INTRODUCTION

A “Control Measure” consists of an arrangement, structural or otherwise, which can be implemented on a construction site to prevent or reduce the amount of erosion or sedimentation which will occur. The application of a control measure on a construction site is referred to as a Best Management Practice (BMP). Despite this distinction, the terms “measure” and “BMP” are often used interchangeably.

When choosing BMPs it is important to have a clear understanding of the type erosion prevention or sediment control that is needed and the corresponding control measures. Control measures can be categorized based on their function, type, and life span. Usually, different categories of measures are combined to create an effective EPSC plan. Section 10.06 discusses the combination of the various categories of measures as each stage of the project progresses. Section 10.08 provides criteria for the design of specific measures. This section discusses the various classifications of the control measures and how these various categories can be combined to create an effective plan.

10.04.2 FUNCTIONAL CLASSIFICATION OF CONTROL MEASURES

Control measures can be classified according to their basic purpose, or function. In general, the three main functions of BMPs are to prevent erosion, reduce sedimentation and control flows in waterways. The following sections examine each of these functions individually.

10.04.2.1 EROSION PREVENTION

The primary means of preventing the pollution caused by excessive quantities of sediment leaving a construction site is to prevent the soil from being eroded in the first place. Reducing the quantity of sediment that is dislodged and transported through a site will minimize the stress placed on the other control measures and this, in turn, will minimize the cost of implementing the EPSC plan. Thus, stabilization is a key component of erosion prevention and sediment control. An area is considered stabilized when the existing soil is held in place by a means sufficient to ensure that it will resist erosion by rain, flow of water, wind, vehicular traffic or any other factor.

Erosion prevention measures either provide a means to hold the soil in place, or to direct stormwater runoff to an erosion-resistant location. Maintaining a vegetative cover on the soil surface is one of the best ways to hold the soil in place and prevent erosion. Once soil is disturbed, temporary or permanent vegetation should be established as soon as possible. Stabilizing construction entrances and roads prevents construction vehicles from causing erosion as they are moved within the construction site. Also the installation of ditch check dams prevents erosion by slowing flow velocities and reducing the energy of concentrated flows. Erosion can also be prevented by directing stormwater runoff to a stabilized location through the use of slope drains, berms, diversion channels, or culverts. Planning and design criteria for these measures can be found in Section 10.08.1.

10.04.2.2 SEDIMENT CONTROL

The main purpose of sediment control measures is to intercept sediment in runoff from the project and retain it on the construction site. This is accomplished either by a filtering mechanism or by slowing flow velocities sufficiently to allow the sediments to drop out. Sediment control measures are secondary treatment devices in that they collect sediments which escape the erosion prevention measures. Since it is theoretically impossible for the erosion prevention measures to be 100% effective, these measures serve as a backup to maximize the effectiveness of the EPSC plan. Sediment control measures can also serve to isolate a construction site by retaining sediments on site, and directing off-site water around the project site. This prevents off-site runoff from being added to on-site runoff, thus minimizing the flow available to erode soils. A few examples of sediment control measures include: various types of silt fence, catch basin protection, sediment traps and sediment basins.

10.04.2.3 FLOW CONTROL

While erosion prevention and sediment control measures are primarily aimed at stabilizing and retaining sediments, flow control measures are used to manage the flow of water in drainage ways, which is one of the main mechanisms causing erosion. Riprap basin energy dissipators and riprap aprons absorb the impact of outflows from culverts, or other high-velocity concentrated flows, allowing them to return to a non-erosive velocity before entering the waterway. Detention basins capture peak flows which may be increased as the result of a project, and release it at a reduced rate, thus preventing the potential for increased erosion in the downstream waterway. These basins may also be used to retain a portion of the stormwater for an extended period of time to allow suspended sediments to drop out. Although these measures tend to be permanent structures, they can be installed early in the project as a complement to the temporary measures.

When a project discharges into a waterway that has been classified by TDEC as impaired due to existing channel erosion, the designer may be required to select a flow control measure to reduce or minimize any increase in the volume of stormwater leaving the site. While this may be considered a post-construction issue, increased flows due to removal of vegetation during a construction project should be considered. For additional information on flow control measures, see Section 10.08.3.

10.04.3 INTENDED LIFE SPAN OF MEASURES

Another way of categorizing EPSC measures is to distinguish between temporary or permanent measures. Typically, permanent measures will remain in place after the completion of construction and will have life spans measured in decades. On the other hand, temporary measures may be installed and removed during various stages of construction and will be completely removed when the project is complete. The life spans of these measures may be measured in months, or even weeks. Some may even exceed their life expectancy and need to be replaced during the course of a long project.

10.04.3.1 TEMPORARY

The majority of measures included in a typical EPSC plan will be temporary. In general, the life span of a specific BMP will depend on the type of measure, the severity of its use, and the maintenance it receives. Proper and routine maintenance will help extend the life of a BMP by keeping it in proper working order and by ensuring that all of the measures continue working together. In this way, sediments will not be concentrated in any one area, placing undue stress on a single measure. Examples of temporary BMPs include check dams, enhanced check dams, silt fence, silt fence with wire backing, and temporary seeding with mulch.

10.04.3.2 PERMANENT

Permanent erosion prevention and sediment control BMPs may include both measures prescribed in the EPSC plan and features which are incorporated into the project design before the plan is written. For example, erosion prevention can be greatly aided, both during construction and long-term, by careful evaluation of slopes and other aspects of the grading plan. Even though these features may not be directly addressed in the EPSC plan, they can play an important role in its success.

Permanent erosion prevention and sediment control measures should be implemented as soon as possible during construction and may be used to complement the temporary measures. However, they usually will not be installed before final grades have been established. Examples of this include culvert outlet protection, ditch lining, and permanent seeding or sod. Channel lining with turf reinforcement mats should also be considered a permanent measure. Unlike erosion control blankets which degrade over time, the geotextile grid in a turf reinforcement mat is designed to resist degradation and remains in place to reinforce the vegetated lining. Thus, this measure may be considered permanent. More information on permanent turf reinforcement mats is available in Section 10.08.1.12 and Chapter 5 of this Manual.

10.04.4 TYPES OF CONTROL MEASURES

Control measures are frequently categorized into vegetative and structural controls. While the meaning of these two categories may be self-explanatory, a few measures do not fit easily into either category. These tend to be operational issues related to the implementation of the EPSC plan as well as general “house-keeping”. This section discusses how these measures may be used together to create ground cover and stabilize the construction site.

10.04.4.1 VEGETATIVE

Vegetative control measures, usually in the form of grasses, can play a key role in controlling erosion. These measures serve to prevent erosion by protecting soil from the impact of raindrops, holding soil particles together, and reducing the velocity of runoff. Vegetation can also help control sedimentation by working as a filter to strain out sediment, debris and other pollutants. Where vegetative measures are feasible, they are usually preferred to structural measures because they provide a relatively inexpensive and highly effective means of controlling erosion. In addition, the use of native grass species can help reduce the need for maintenance. Where possible, the ideal vegetative control measure would be to minimize the disturbed area to preserve the existing vegetation as much as possible.

It is important to establish vegetation as soon as possible on areas where a grading operation has been completed, or where a graded area is to be left inactive for more than 14 days. Significant vegetation growth becomes difficult after the topsoil has been removed from the surface by erosion. The remaining subsoil usually has very little available nitrogen for plants and minimal water holding capacity. In these conditions, root development is very week and plant establishment becomes difficult. Thus, temporary seeding should be carried out as soon as possible and permanent seeding should be carried out only when stockpiled topsoil has been replaced on the site. On sloping sites, or in other situations where establishment might be difficult, erosion control blankets may be used to help hold seed and fertilizer in place and to encourage germination.

Vegetative measures usually consist of seeded grasses. In many situations, these grasses should be protected with mulch as specified in the TDOT Standard Specifications. In situations where erosive forces are expected to be somewhat greater, such as on slopes or in side ditches, erosion control blankets may be used to protect the seed and promote growth. Turf reinforcement mats may be used in other situations where vegetated measures may need to be reinforced on a permanent basis. Section 10.08.1 provides guidance for the selection of erosion control blankets and turf reinforcement mats and Section 5.04 provides guidance on selecting linings for ditches and other waterways.

10.04.4.2 STRUCTURAL

Although vegetated control measures are considered the primary tool for erosion prevention and sediment control, structural measures may be used to isolate areas of active construction or to protect other areas where vegetation cannot be established. Some of the uses of structural measures include:

- diverting site runoff (as well as run-on flow) around exposed areas
- breaking up steep or long slopes
- slowing velocity of flows sufficiently for suspended sediments to drop out
- providing armor against construction vehicle traffic
- providing armor against high-velocity or concentrated flows

Temporary structural BMPs are usually removed at the completion of the construction project. In larger construction projects, these measures could be removed and rebuilt in other locations as needed to accommodate the proposed construction staging. Examples of these measures include ditch checks, various types of silt fence, construction road exits or entrances, temporary stream crossings, slope surface roughening and flow diversion berms.

Permanent structural measures will remain in place after completion of the project but should be installed as early as possible during the course of construction. Examples of permanent structural measures include riprap basin energy dissipators and riprap aprons at culvert outlets. In addition, a sediment basin may be reconstructed (modified) at the end of a project to act as a permanent detention basin. These and other structural measures are discussed in Section 10.08.

Temporary and permanent structural controls are not permitted to be installed in a stream or a wetland without an ARAP; and thus, their use in a stream should be avoided when possible. When temporary stream crossings, fords, etc. (i.e. in-stream items) are necessary for a project, a permit will be required from the Environmental Division.

10.04.4.3 OTHER

Control measures which do not fit into the vegetative or structural categories tend to be related to operational issues. The BMP of primary importance to the designer in this category is Construction Staging. This involves planning the installation of EPSC measures so that the appropriate measures are in place as the construction progresses from initial clearing to the final construction of the roadway or other facility. Construction staging is discussed in detail in Section 10.06.

Measures such as street sweeping, dust control and other matters of “house-keeping” may also be included in this category. For example, adding water for dust control to the construction plans (see Figure 10-8) will reduce blowing dust from the site or maintaining a stabilized construction access (see Section 10.08.1.3) to and from an adjacent roadway will aid in minimizing off-site sediment tracking. Although these matters may be discussed in the Erosion Prevention and Sediment Control Notes, they are not necessarily design matters and are not covered in this Manual.

Figure 10-8
Watering the Construction Site for Dust Control
Reference: Ohio DNR (2005)

10.04.5 DESIGN ELEMENTS WHICH ASSIST IN EROSION PREVENTION

Several elements of the roadway design can contribute to the overall success of the temporary erosion prevention measures, even though they may not be directly addressed in the EPSC plan. These design elements break up long slopes or minimize opportunities for flows to concentrate, thus allowing the erosion BMPs for the project to function more efficiently or even reducing the need for these measures. This section presents a number of basic design elements which could be incorporated into a project to supplement erosion prevention.

Slope of Cuts or Fills: Slope steepness and slope length are critical factors in determining the volume and velocity of runoff and its associated erosion. As both slope length and steepness increase, the rate of runoff increases and the potential for erosion is magnified, increasing the effort required to provide stabilization. Thus, flatter slopes are desirable where they can be accommodated by the right of way, and where they can be economically justified. Normally, the slope of a cut or fill should be as specified in the Roadway Design Standard Drawings. Flatter slopes may be used only with the approval of the Design Manager.

In general, a 3H:1V slope is the steepest which may be stabilized by seeded vegetation (although crown vetch may be used on steeper slopes), and is also the steepest slope which may be safely mowed. Slopes steeper than 3H:1V may also present more stringent requirements for stabilization. Slopes with grades of 35 percent or steeper are required to be stabilized not later than 7 days after construction activity has ceased (temporarily or permanently). While the designer cannot control a contractor's schedule and sequence of construction, they should be aware that the need for control measures such as temporary seeding with mulch may be needed in the final construction documents to meet these time restrictions. In addition, slope lengths longer than 100 feet should be avoided. Fill slopes are usually more erodible than cuts through naturally deposited material. Thus, erosion prevention measures on fill slopes may require extra attention.

Although slope stability may primarily be a geotechnical issue, it is related to erosion prevention since a slope failure can produce very large amounts of sediment. In general, vegetation can stabilize only the material in the top 3 feet of the slope. Thus, the underlying materials must be stable for the proposed slope. The designer should pay particular attention to this issue where conditions such as water-bearing strata and soils high in silt content are present.

Bench Terraces: Where right-of-way or other limitations preclude the use of slopes flatter than 3H:1V, benched terraces can be used to break up a slope and divert runoff to an erosion-resistant outlet. Bench terraces are also suitable for very long slopes where rainfall on the slope is expected to produce significant runoff. Each bench should be at least 6 feet wide to allow for mowing equipment and should be graded back to the face of the slope to form a small channel. These benches should be constructed either along the contour or should slope gradually to an erosion-resistant waterway. It is recommended that the vertical distance between benches not exceed 30 feet for cut slopes and 25 feet for fill slopes. Where the slope between benches is steeper than 3H:1V, the surface should be roughened as described in Section 10.08.1. Benched terraces should not be constructed on non-cohesive soils such as deep sands. This measure is suitable for slope lengths greater than 100 feet. However, the TDOT Geotechnical Section shall be consulted in any case where benches are to be utilized as erosion prevention measures. This BMP may be incorporated into the project design as a permanent feature, or it may also be a part of the EPSC plan as a temporary measure.

Stair Step Grading: This practice may be carried out on any material soft enough to be ripped by a bulldozer. Slopes consisting of soft rock with some subsoil are particularly well-suited to stair step grading. The horizontal faces provide a level surface where vegetation can become established and which serve to catch rock or other sediments which may slough from above. The horizontal "step" should be sufficiently wide to accommodate the operation of a bulldozer. It is recommended that the ratio of the horizontal distance to the vertical cut distance should be at least 1.5H:1V, and the step should slope slightly toward the vertical wall. Individual vertical cuts should not be more than 30 inches on soft soil materials and not more than 40 inches in rocky materials. This method is typically not applied on slopes flatter than 3H:1V. Where the slope length exceeds 20 feet, the TDOT Geotechnical Section should be consulted.

This BMP may be included in the project design as a permanent feature, or it may also be a part of the EPSC plan as a temporary measure.

Vertical Rounding: Sharp breaks either where two slope faces intersect or where a slope intersects the existing ground can create troughs in which runoff can concentrate. These concentrated flows, in turn, increase the potential for erosion in those areas. Providing curved transitions between slopes can help keep runoff in a diffused form, which will minimize its erosive potential.

Vertical rounding should be applied both at the top and at the bottom of slopes, as shown in the Roadway Design Standard Drawings. At the top of both cut or fill slopes, rounding the transition between the slope and the relatively level ground above it helps to prevent the erosion which can occur at a sharp break in slope. The treatment at the toe of the slope will depend on whether the adjacent ground is graded towards the slope or away from it. If the existing ground is graded away from the slope, it will be sufficient to provide a rounded transition and allow the runoff to continue flow away from the slope. Where the existing ground is graded back toward the slope, a special ditch should be provided at the toe of the slope to convey the runoff to an erosion-resistant outlet.

Ditch Grades: Where special ditches are proposed, their profiles should be as simple as possible. The potential for erosion at a break in ditch grade is greater than on a continuous slope. Where a break in grade is necessary to accommodate a steep ditch slope, it is preferable from the standpoint of erosion prevention to place the steep portion of the ditch at the upper end of the ditch instead of near its outlet. Where site conditions make this arrangement difficult, the designer should make an effort to provide a section of relatively flat ditch grade just upstream of the outlet. This will help to minimize the velocity of the flow as it enters the receiving stream thereby reducing the potential for scour. Other measures to reduce velocity, such as riprap energy dissipators may be applied as well.

10.04.6 COMPUTATION OF EROSION PREVENTION AND SEDIMENT CONTROL QUANTITIES

The designer's development of the erosion prevention and sediment control plan should be done in such a manner as to comply with the anticipated construction staging (see Section 10.06) for the particular project. All linear measurements for the erosion prevention and sediment control quantities may be determined from the erosion prevention and sediment control plan sheets as they are developed.

2 and 3-Lane Highways	
Length of project	**Estimated Time**
Less than 1 mile	16 to 32 weeks *
1 mile to 2 miles	20 to 38 weeks *
2 miles to 3 miles	28 to 44 weeks *
over 3 miles	9 to 13 weeks per mile
4 and 5-Lane Highways	
Length of project	**Estimated Time**
Less than 1 mile	24 to 36 weeks *
1 mile to 2 miles	32 to 42 weeks *
2 miles to 3 miles	38 to 54 weeks *
over 3 miles	12 to18 weeks per mile
* Do not accumulate times Add 65% to the above times for an urban (curb and gutter) section Reduce the above times by 20% for SIA projects	

Table 10-5
Estimated Duration of Time for Roadway Projects

The designer should bear in mind that the quantities for many of the erosion prevention and sediment control pay items are based on an expected life span of this item as well as the construction staging. To make the calculations for quantities on a particular pay item, the designer should:

1. Place the necessary erosion prevention and sediment control pay items, as needed, on the EPSC plan for the project, taking into account as much as possible the anticipated staging of the construction activities.

2. Divide the estimated duration of the construction activities by the estimated life of each erosion prevention and sediment control pay item to obtain an adjustment factor for each pay item.

3. Multiply the adjustment factor derived above by the computed quantity as taken from the erosion prevention and sediment control plan to obtain the necessary quantity for each pay item. This quantity is then placed in the appropriate column in the erosion prevention and sediment control quantity table on the first EPSC plan sheet.

Table 10-5 can provide assistance in estimating construction times for projects of varying sizes. The Notice to Contractors can also provide useful information by allowing a comparison between a given project and similar projects previously completed. To estimate the total construction time in weeks for a given project, divide the total number of working days provided in the Notice to Contractors by *3.85*.

10.04.6.1 CONVERTING CUBIC YARDS TO TONS

Pay items for a number of aggregate or rock materials used for Erosion Prevention and Sediment Control Plans are in units of tons. However, computing these quantities usually involves determining the required volume of the material. Thus, it is necessary to convert the computed volumes into weights. The volume of a given material in CY may be multiplied by the conversion factors presented in Table 10-6 to accomplish this purpose.

Item Number and Description	Conversion Factor
Item Number 709-05.06: Machined Riprap (Class A-1) Item Number 709-05.07: Machined Riprap (Class A-2) Item Number 709-05.05: Machined Riprap (Class A-3) Item Number 709-05.08: Machined Riprap (Class B) Item Number 709-05.09: Machined Riprap (Class C)	1.75 Tons/CY
Item Number 303-10.01, Mineral Aggregate (Size 57)	1.49 Tons/CY

Table 10-6
Conversion Factors from Cubic Yards to Tons for EPSC plan Items

10.04.6.2 SEDIMENT REMOVAL

Sediment should be removed from silt fences, sediment traps, enhanced rock check dams, natural areas, sediment basins, and other locations on a project where sediment will be trapped. For most BMPs, sediment removal should be performed when the design capacity of the measure has been reduced by 50 percent. Sediment removal is calculated based on the *disturbed* area of the project; not the total project area. Sediment transport from undisturbed project areas may be omitted from the sediment removal calculations, as the amount is generally considered insignificant. However, when upland areas are expected to produce significant amounts of sediment due to their existing conditions, the designer should include this sediment volume in their final computations. Attempts to divert sediment-laden “run-on” flows away from the temporary project sediment controls should be made part of the final project plans.

Sediment removal should be calculated as follows:

Sediment Removal (C.Y.) = Disturbed Area (acres) x 34 (CY/acre)

For widening projects the volume of sediment removal is calculated as follows:

Sediment Removal (C.Y.) = Disturbed Area (acres) x 17 (CY/acre)

An additional quantity is added for sediment removal from sediment basins and sediment traps. The additional sediment removal for sediment basins and sediment traps is calculated as follows:

Sediment Removal (C.Y.) = $1.25V_w$

V_w = Total volume of wet storage in all sediment basins and sediment traps

SECTION 10.05 – THE EROSION PREVENTION AND SEDIMENT CONTROL PLAN

10.05.1 REQUIREMENTS OF THE EPSC PLAN

The Erosion Prevention and Sediment Control plan is a set of plan sheets and notes which explain and illustrate the erosion prevention and sediment control measures to be used on a roadway project. These plans

- set forth the vegetative and structural BMPs to be used at each stage of the plan
- describe the operational BMP requirements such as maintenance schedules, seeding practices, etc.
- provide tabulated quantities for the EPSC measures to be installed

Usually, these plans will be presented in two or more stages, as described in Section 10.06. Occasionally, additional sub-stages may be required for construction of box bridges, or similar structures during the clearing and grubbing stage. As shown in Figure 4-2 of the Roadway Design Guidelines, the EPSC plan sheets are included in the construction plans immediately following the Culvert Section Sheets. The EPSC plan consists of the Special Erosion Prevention and Sediment Control Notes, Erosion Prevention and Sediment Control Legend, Erosion Prevention and Sediment Control Quantity Tabulations, and the Erosion Prevention and Sediment Control Sheets. The Special EPSC notes provide additional specifications for the application of the measures shown in the plan. The General Erosion Prevention and Sediment Control Notes are located in the project plans with the other project related General Notes. These items are an integral part of the overall Stormwater Pollution Prevention Plan.

10.05.1.1 STORMWATER POLLUTION PREVENTION PLAN (SWPPP)

A Notice of Intent (NOI) and a Stormwater Pollution Prevention Plan (SWPPP) are required to be submitted to the Tennessee Department of Environment and Conservation for all projects which disturb one (1) acre or more of land. The SWPPP is a written plan which identifies the potential for various kinds of pollution which could occur due to a construction project, and describes the measures which will be used to minimize this pollution from entering streams or other waterways.

The permits and the SWPPP will be prepared by the Environmental Division. The designer will prepare the Erosion Prevention and Sediment Control Plans. The EPSC plans are an integral part of the SWPPP and will be included in the SWPPP. The designer should be aware that in-stream EPSC controls will likely require the need for an ARAP and a Section 404 permit; and thus, the use of EPSC measures in streams should be avoid whenever possible. A more complete discussion of the water quality permit requirements for a project can be found in Section III of the Roadway Design Guidelines.

10.05.1.2 ADDITION OF THE EPSC PLAN INTO FIELD REVIEW AND FINAL ROW PLANS

Project plans should be submitted to the Environmental Division and Design Division Standards and Quality Assurance Office at all major plan development milestones. The Erosion Prevention and Sediment Control Plan sheets should be included in the plans submitted for Right-of-Way Appraisals and Acquisition. They should also be included in right-of-way field review and construction field review plans. The Erosion Prevention and Sediment Control Plan should be complete to the extent possible. The EPSC plan should include the Special EPSC Notes, EPSC Legend, and EPSC Site Plan Sheets when the plans are printed for the right-of-way field review; however, EPSC Quantity Tabulations and General EPSC Notes will not be required until the plans are printed for construction field review. Typically, the Environmental Division and Design Division Standards and Quality Assurance Office will provide comments on the EPSC plan sheets. These comments should be addressed by incorporation into the plans or by a formal response to the respective office. Any required permit submittals to TDEC will be made by the Environmental Division.

Once plans are formally submitted, any changes to the EPSC plan sheets due to design revisions, right-of-way revisions, permit requirements, mitigation requirements, ecological evaluation requirements, erosion prevention and sediment control notes revisions, addition or deletion of sheets, etc. will require a formal plan revision.

The Design Manager should contact the Environmental Division when EPSC plans are revised to determine whether revised plan sheets or other information should be submitted to them.

10.05.1.3 STORM FREQUENCY FOR DESIGN OF EPSC MEASURES

A number of the control measures which may be utilized in an EPSC plan require detailed design based on the expected peak discharges at a site. In general, EPSC best management practices should be designed to accommodate the 5-year/24-hour storm event. However, when the Environmental Division has completed the Permit Assessment prior to the submittal of Right-of-Way Plans, and has determined that the waters receiving runoff from the project are not listed as Exceptional Tennessee Waters or sediment-impaired (see definitions in the Appendix), the 2-year peak discharge may be used for BMP design, subject to the approval of the Design Manager. Any volume-based measures which require specific design should be based on the 24-hour storm duration. Chapter 4 of this Manual provides procedures which may be used to determine peak discharges, intensities, or runoff flow volumes for design.

10.05.2 OBJECTIVES OF THE EPSC PLAN

To produce an effective Erosion Prevention and Sediment Control (EPSC) design, proper planning of control measures must be implemented for all stages of the design. The basic concept of providing effective, efficient, and practical erosion prevention and sediment control should be considered when determining the locations and types of BMPs. Where possible, offsite run-on water should be diverted away from disturbed areas, and all on-site stormwater runoff should be treated with an appropriate BMP for sediment removal.

The following seven principles should be considered during the design of the EPSC plans. Even though the designer often has little control of over some of these issues, an awareness of them will be of value in designing an effective plan.

1. **Plan the development to fit the topography, soils, drainage and natural vegetation.** Detailed planning should be employed to assure that roadways, structures, and other permanent features of the project conform to the natural characteristics of the site. Information on natural drainage ways, surface waters, and existing drainage patterns is provided in the drainage map. Areas subject to flooding

should be avoided and floodplains should be kept free, if possible, from fill and other potentially erodible development. Areas with steep slopes, erodible soils and soils with severe limitations for the intended uses should not be utilized without first overcoming those limitations through sound engineering practices. For example, long steep slopes can be broken up by benching, terracing (with proper coordination with the Geotechnical Section), or by constructing flow diversion structures so that erosion problems will not occur or be transferred down the grade. Erosion Prevention and Sediment control installation and maintenance costs can be minimized by selecting a site suitable by its nature for a specific proposed activity, rather than by attempting to modify the site.

2. **Apply perimeter control practices to protect disturbed areas from offsite flows and prevent sedimentation damage to areas downstream.** Use sediment control measures to isolate the construction site from surrounding properties. This includes diverting off-site flows around the site, and most importantly, capturing any sediment produced on site so that it will not cause off-site pollution. Sediment is generally retained by two methods. The first includes filtering runoff as it flows through an area and the second is by impounding the sediment laden runoff for a period of time so that the soil particles settle out. For example, a vegetated buffer strip should be installed or maintained between a water course and the project site.

3. **Minimize disturbed area and duration of the exposure.** The best method of controlling sediment is to prevent erosion in the first place. Thus, when earthwork is required and natural vegetation is removed, the area and the duration of exposure should be kept to a minimum. The project site should be phased so that the only exposed area is the area which is actively being developed. All other areas should have a good cover of temporary or permanent vegetation, mulch, or erosion control blankets. Grading should be completed as soon as is practical after beginning the project. Once grading has been completed, permanent vegetation should be established as soon as possible.

   No more than 50 acres of active soil disturbance is allowed at any time during the construction of a TDOT project. Off-site borrow or waste areas are to be included in the total disturbed area, if the borrow or waste area is exclusive to the project per TDOT's Waste and Borrow Manual. The designer will compute the total disturbed area as the total area inside the slope lines plus the area inside a 15' wide strip immediately adjacent to the slope lines.

   The total disturbed area is an estimate and should be rounded to the nearest acre.

   The proposed <u>disturbed</u> area will determine the number of EPSC plan stages that must be provided in the project plans. See Section 10.06.2 for additional EPSC plan staging requirements based on total disturbed area. Undisturbed areas should be located and labeled on the EPSC plans as such (see Section 10.05.3.2).

4. **Stabilize disturbed areas immediately.** All vegetative, structural, and flow control measures, whether they are permanent or temporary should be employed as quickly as possible after the land is disturbed. Temporary vegetation and mulches may be used in areas where establishing permanent vegetation is not practical. These temporary measures should be employed immediately after rough grading if a delay in

obtaining finished grade is anticipated. All roadways, parking areas, and paved areas should be stabilized with a gravel sub-base, temporary vegetation, or mulch.

5. **Apply erosion prevention practices to minimize on-site damage.** As much as possible, erosion prevention practices should be used to prevent excessive sediment from being produced. Sediment control is more difficult and expensive when erosion is not controlled at the source. Ideally, all erosion would be prevented on a site. However, it is usually impractical to prevent sheet and rill erosion, since grading requires that at least some soil be exposed and complete prevention of erosion would require a very large number of BMPs. More practical goals are to prevent erosion in the form of gullies and to minimize the area of soil exposed at any given time. A number of practices are available to achieve these goals. Exposed soils which are to be left idle for more than 14 days can be covered with temporary or permanent vegetation, mulch, or erosion control blankets. Stabilization of slopes steeper than 35 percent is required not later than 7 days after activity on the slope has ceased, either temporarily or permanently. Special land grading methods such as roughening a slope on the contour or tracking with a cleated dozer may also be used. Temporary berms or other diversion structures can be used to direct surface runoff away from disturbed soils.

6. **Keep runoff velocities low and detain runoff on the site.** The removal of existing vegetative cover from a site tends to decrease the permeability of the soil and create a smoother surface. As a result, both the volume and the velocity of runoff from the site will increase. These potential increases should be considered in the design of the EPSC plan. Using shorter, flatter slopes and preserving natural vegetative cover can keep stormwater velocities low and limit the potential for erosion. Runoff can be conveyed from the site to a stable outlet using storm drains, diversion berms, riprap channels or other similar measures. Peak discharge rates should also be calculated so that these conveyance systems can be designed to withstand the computed peak velocities and shear stresses. Stormwater retention or detention structures should be considered when there is a potential for flooding and damage to downstream facilities due to increased runoff from the site. All facilities to keep runoff velocities low and retain runoff on the site should be operational at the start of construction.

7. **Implement a thorough maintenance and follow-up program.** This principle is essential to the success of the other six principles. Periodic checks of the erosion prevention and sediment control practices will assist in effectively protecting a site. An "end of day check" should be made to ensure that all control practices are working properly. Drainage patterns should be monitored and the erosion prevention and sediment controls adapted accordingly as these patterns can change during different stages of construction. A supply of materials needed to construct the control practices for a project should be readily available to enable timely repairs.

These seven principles can be used to provide an effective and practical design for the EPSC plan.

10.05.2.1 BUFFER ZONES FOR EXCEPTIONAL TENNESSEE WATERS OR SEDIMENT IMPAIRED STREAMS

For sites that contain, or are constructed adjacent to Exceptional Tennessee Waters or sediment-impaired streams, a natural riparian buffer zone consisting of undisturbed existing vegetation should be left in place between the limits of the disturbance and the top of the stream bank. It should be noted that these waters could also include lakes, ponds, wetlands, springs, and seeps. In the case of streams, the width of the buffer zone is measured from the top of stream bank to the limit of disturbance. For other water sources listed, the edge of water to the limit of disturbance should be used to determine the buffer width.

The buffer zone should be 60 feet in width (along both sides of a stream), measured from the top of the stream bank to the disturbed area. The buffer may be as narrow as 30 feet, provided that the average width of the entire buffer zone is 60 feet. Buffer zones adjacent to Exceptional Tennessee Waters or sediment-impaired streams shall not be less than 30 feet wide at any measured location.

Attempts should be made for construction activities not to take place within the buffer zones. When the designer is unable to provide or maintain the required buffer strip, it may be possible to provide equivalent sediment control measures (BMPs) along the edge of the proposed disturbed area. In this situation, the designer should provide justification why it was not possible to provide or maintain the required buffer zone, along with documentation showing that the proposed sediment control measures provide a level of protection equivalent to a buffer zone.

For sites with an ARAP (i.e. temporary stream crossings, bridge crossings, box culverts, etc.), the buffer zone requirements provided herein do not apply, as the requirements in the valid ARAP will govern. Additionally, when existing land use (roadway, bridges, utility lines, etc) already encroaches on a buffer; an exemption to these requirements is allowed for the portion of the buffer that contains the “footprint” of the existing land use or feature.

A buffer zone should not be considered the primary means of controlling project derived sediment. A natural vegetative buffer alone will not provide adequate sediment control. Additional sediment control measure should be provided to isolate the project from the buffer zone. These additional measures may consist of BMPs such as silt fence with wire backing, linear enhanced rock check dams, sediment tubes, filter socks, mulch berms, or a combination of these measures that will provide the desired result.

Buffer zones should be clearly identified on the project EPSC plans. The use of high-visibility orange fencing may be required to keep construction equipment out of the buffer zone.

Projects with approved right-of-way plans prior to June 16, 2005 are exempt from the buffer zone requirements of this section.

10.05.2.2 BUFFER ZONES FOR ALL OTHER STREAMS

For all other projects adjacent to streams that do not meet the classification requirements of 10.05.2.1, a vegetated buffer zone is also required between the top of the stream bank and the proposed disturbed area. To the maximum extent practical, a natural riparian buffer zone with an average width of 30 feet (on both sides of a stream) should be preserved; provided that at any measured location, the width of the buffer is not less than 15 feet.

Attempts should be made for construction activities not to take place within the buffer zones. Where the required buffer zone cannot be preserved, design of equivalent measures is required, and justification as to the reason for not maintaining the buffer zone should be provided in the project file.

For sites with an ARAP (i.e. temporary stream crossings, bridge crossings, box culvert, etc.), the buffer zone requirements provided herein do not apply, as the requirements in the valid ARAP will govern. Additionally, when existing land use (roadway, bridges, utility lines, etc) already encroaches on a buffer; an exemption to these requirements is allowed for the portion of the buffer that contains the “footprint” of the existing land use or feature.

Buffer zones should be clearly identified on the project EPSC plans. The use of high-visibility orange fencing may be required to keep construction equipment out of the buffer zone.

Projects with approved right-of-way plans prior to February 1, 2010 are exempt from the buffer zone requirements of this section.

10.05.3 INFORMATION SHOWN ON THE EPSC PLAN

The erosion prevention and sediment control plan sheets are organized into two general sections. The first section contains the Special EPSC Notes, EPSC Legend, and Tabulated EPSC Quantities. The Special EPSC Notes describe the project specific operational practices and standards which are to be applied in implementing the proposed EPSC measures. The General EPSC Notes should be located in the project plans with the other project related General Notes. The second section consists of site plan sheets showing the locations of the proposed EPSC measures, along with any additional performance notes which may be required. An EPSC plan will usually require a complete set of site plan sheets for each stage of the plan, as described in Section 10.05.3.2. A single-stage EPSC plan depicting all EPSC devices to be used on the project is not acceptable (See Section 10.06).

EROSION PREVENTION AND SEDIMENT CONTROL QUANTITIES

	ITEM NO.	DESCRIPTION	UNIT	QTY.
	209-02.07	18" TEMPORARY SLOPE DRAIN	L.F.	400
	209-05	SEDIMENT REMOVAL	C.Y.	370
(1)	209-08.02	TEMPORARY SILT FENCE (WITH BACKING)	L.F.	3400
	209-08.03	TEMPORARY SILT FENCE (WITHOUT BACKING)	L.F.	5200
ALT.	209-09.03	SEDIMENT FILTER BAG (15' X 15')	EACH	1
ALT.	209-10.01	TEMPORARY DEWATERING STRUCTURE	C.Y.	592
(2)	303-10.01	MINERAL AGGREGATE (SIZE 57)	TON	67
	709-05.07	MACHINED RIPRAP (CLASS A-1)	TON	60
(3)	740-10.03	GEOTEXTILE (TYPE III) (EROSION CONTROL)	S.Y.	740

FOOTNOTES

(1) INCLUDES 400 L.F. FOR TEMPORARY SEDIMENT FILTER BAG

(2) INCLUDES 47 TONS FOR TEMPORARY SEDIMENT FILTER BAG

(3) INCLUDES 400 S.Y. FOR TEMPORARY SEDIMENT FILTER BAG

Figure 10-9
Typical Tabulation of Quantities for Erosion Prevention and Sediment Control

10.05.3.1 GENERAL AND SPECIAL EROSION PREVENTION AND SEDIMENT CONTROL NOTES

The erosion prevention and sediment control notes for a project will usually consist of general and special notes. These notes consist of lists of instructions to the contractor and should be developed as described in Sections 4-135.00 and 4-135.05 of the Roadway Design Guidelines. The first sheet of the EPSC plan should include the Special Erosion Prevention and Sediment Control Notes, the Erosion Prevention and Sediment Control Legend, and the Tabulated Erosion Prevention and Sediment Control Quantities. The General Erosion Prevention and Sediment Control Notes should be located in the project plans with the other project related General Notes. Each of these items is discussed below.

General Erosion Prevention and Sediment Control Notes: The General Erosion Prevention and Sediment Control Notes should be located in the project plans with the other project related General Notes. They are general in nature and describe practices which are to be maintained on all projects. Some of the issues discussed in these notes include frequency of inspection; the limiting of exposed areas; and proper protection of waters of the State. Sections 4-135.00 and 6-190.00 of the Roadway Design Guidelines should be used when developing the General EPSC Notes for the project and for an up-to-date list of these notes. Although these notes are general, it may be that not all of them will apply to a specific project. In such cases, the unneeded notes should not be included in the plan. Occasionally it is necessary to modify one of the general notes to address project-specific conditions. When this occurs, the affected note should be removed from the General Notes and placed with the Special Erosion Prevention and Sediment Control Notes, described below.

Special Erosion Prevention and Sediment Control Notes: The Special Erosion Prevention and Sediment Control Notes found in Section 6-290.00 of the Roadway Design Guidelines shall be added to the first sheet of the EPSC plans, unless indicated otherwise. They provide project specific information on requirements for the proposed erosion prevention and sediment control measures, as well as specific steps the contractor is to take in the execution of the EPSC plan. Placement of these notes shall follow the guidance indicated in Section 6-290.00 of the Roadway Design Guidelines to determine if a particular note is required.

As needed the designer should add any additional Special EPSC Notes which provide project specific information on requirements for the proposed EPSC measures, as well as specific steps the contractor is to take in the execution of the EPSC plan. These notes should also be added to the first sheet of the EPSC plans.

Any additional Special EPSC Notes provided by the Environmental Division shall be shown on the first sheet of the EPSC plans.

Special Erosion Prevention and Sediment Control Notes for Utility Relocations: Usually, utilities will be relocated by others prior to the commencement of the roadway construction project. However, when a project does include utility relocation work, the Special Erosion Prevention and Sediment Control Notes for Utility Relocations should be included with the Special EPSC Notes in the EPSC plans. The current version of the Roadway Design Guidelines should be consulted for an up-to-date list of these notes.

Special Erosion Prevention and Sediment Control Notes for NPDES Permitted Projects: When a project requires a NPDES permit, the Special Erosion Prevention and Sediment Control Notes for NPDES should be included with the Special EPSC Notes in the EPSC plans. The current version of the Roadway Design Guidelines should be consulted for an up-to-date list of these notes.

Erosion Prevention and Sediment Control Legend: The Erosion Prevention and Sediment Control Legend should be added to the first sheet of the EPSC plans. The EPSC Legend provides a list in tabular form of BMPs to be used on a project. This list shows the symbol which will be used to represent a specific measure on the site plan sheets, as well as a description of the measure and the applicable TDOT Standard Drawing number. Section 10.08 provides a full list of the measures which may be used on a project and shows the symbols which are used to represent those measures on the EPSC plan. The legend should include only the specific measures which are to be used on a given project. Figure 10-10 shows a typical Erosion Prevention and Sediment Control Legend in proper format. The TDOT standard symbol for the BMPs to be used on the project should be in the left column, the item description should be in the center, and the Standard Drawing number should be in the right column.

Tabulated Erosion Prevention and Sediment Control Quantities: The Tabulated EPSC Quantities should be added to the first sheet of the EPSC plans. These tables provide a listing of quantities specific to the erosion prevention and sediment control practices to be applied on a project. A separate table should be provided for each stage of the EPSC plan. The erosion prevention and sediment control quantities in these tables should be added to the total project quantities listed on the Estimated Roadway Quantities sheets. Additional information on calculating erosion prevention and sediment control quantities may be found in Section 10.04.6. An example of these tabulated quantities is provided in Figure 10-9.

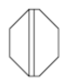
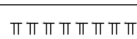
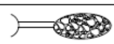
EROSION PREVENTION AND SEDIMENT CONTROL LEGEND		
SYMBOL	ITEM	STD. DWG.
	DEWATERING STRUCTURE	EC-STR-1
	SEDIMENT FILTER BAG	EC-STR-2
* SF * SF * SF *	SILT FENCE	EC-STR-3B
* SFB * SFB * SFB *	SILT FENCE WITH WIRE BACKING	EC-STR-3C
	ROCK CHECK DAM (TRAPEZOIDAL DITCH)	EC-STR-6
	ROCK CHECK DAM (V-DITCH)	EC-STR-6
	ENHANCED ROCK CHECK DAM (TRAPEZOIDAL DITCH)	EC-STR-6A
	TEMPORARY BERM	EC-STR-27
	TEMPORARY SLOPE DRAIN	EC-STR-27

Figure 10-10
Typical Erosion Prevention and Sediment Control Legend for EPSC plan Sheets

10.05.3.2 EXISTING AND PROPOSED SITE FEATURES

Following the erosion prevention and sediment control notes sheets, the EPSC site plan sheets consists of roadway plan sheets showing the proposed construction with symbols denoting the intended locations of all BMPs, as well as any needed performance notes. Since all projects with one or more acres of disturbance will require a staged EPSC plan, a complete set of roadway plan sheets will be required for each stage. When the EPSC plan includes a sub-stage, as described in Section 10.06, only the sheets pertinent to that sub-stage need to be included. The sheets for the sub-stage should follow the sheets for the main stage to which it applies.

At a minimum, the following features should be included on the erosion prevention and sediment control site plan sheets:

- North arrow and scale
- Roadway centerline and stationing
- Existing and proposed right of way lines
- Existing and proposed elevation contours (see below)
- Edges of cut and fill lines
- Proposed cross drains, side drains, and end sections
- Existing waterways, wetlands, and ponds
- Stream relocations
- Flow direction for proposed special ditches
- All temporary erosion prevention and sediment control measures
- All permanent erosion prevention measures, including riprap (final stage)
- Names of named streams and receiving waters
- Energy dissipators for culverts, whether riprap or concrete (if used as an EPSC item)
- Performance notes on application of BMPs, restrictions on clearing, sensitive areas, etc.
- Proposed drainage easements
- Stormwater outfall locations
- Sinkholes, Wetlands and Wet Weather Conveyances numbered (i.e. WWC-1, WTL-4, etc…)
- Limits of land disturbance/clearing
- Undisturbed areas should be labeled as such on plans
- Buffer Zones
- Beginning and end stations of the project for mainline and side roads

The following features are recommended to be included on the erosion prevention and sediment control plan sheets and are at the designers discretion:

- Existing features, such as homes; drives, fences, etc.
- Proposed roadway edges of pavement
- Existing public roads, with names
- Notes needed to describe the temporary measures (such as bottom width and side slope of diversion channels)

A complete depiction of the existing (pre-construction) contours for a project should be shown either on Stage 1 EPSC site plans sheets or on separate Existing Contour sheets. When they are used, Existing Contour Sheets should be developed at the same scale as the EPSC site plan sheets. Proposed (post-construction) contours should be shown either on the final stage of the EPSC plan sheets or on separate Proposed Contour sheets. Again, when separate Proposed Contour sheets are used, they should be at the same scale as the EPSC plan sheets. When the existing and proposed contours are shown on separate sheets, these sheets should be included in the plans following the EPSC plan sheets. Refer to the Roadway Design Guidelines and current Instructional Bulletins for additional information.

Additional information on the preparation of EPSC plan sheets may be found in the Erosion Prevention and Sediment Control Plan checklist provided in Section 1 of the Roadway Design Guidelines. Information on how these items are to be represented in a staged EPSC plan can be found in Section 10.06.

10.05.3.3 STANDARD EPSC PLAN SYMBOLS

The EPSC plan sheets should show the TDOT approved standard EPSC symbols at the intended location of the BMP on the EPSC site plan sheets. Each required device should be shown by graphical representation on the plan along with any additional site specific instructions. Standard Drawings RD-L-5, RD-L-6, and RD-L-7 provide a list of the available BMPs along with their approved standard plan symbol.

10.05.3.4 STORMWATER OUTFALLS

Designers will be responsible for identifying and labeling stormwater outfalls on all stages (and sub-stages when necessary) of the Erosion Prevention and Sediment Control plan for projects which require a Storm Water Pollution Prevention Plan (SWPPP). Outfalls will generally be located where concentrated flow leaves the site, flows off the State's ROW, and at locations where stormwater will directly enter jurisdictional or project features such as streams, wetlands, sinkholes, MS4, etc.). The area of drainage area(AC) and the average slope (%) of the drainage area to each outfall shall also be provided by the roadway designer for each stage of the EPSC plan. Outfall labeling shall be included on right-of-way field review and all subsequent plans. The SWPPP Consultant shall be responsible for verifying the stormwater outfalls during the right-of-way field review.

Outfalls are defined as stormwater point source discharges from construction sites which pollutants are or may be discharged into waters of the State of Tennessee (i.e. streams, wetlands, etc.). A point source is any discernible, confined, and discrete conveyance, including but not limited to permanent (final) pipes, culverts, ditches, channels, flumes, curbs, curb and gutters, catch basins and inlets, and the ends of permanent diversions. A stream flowing through a site is not an outfall.

Outfalls may also be temporary, but necessary for construction activities and should be identified as such on the EPSC plans when known at the time of plan preparation. Examples of temporary outfalls may include temporary ditches, outlets to temporary pipes or culverts used with run-arounds, and diversions. All temporary outfall locations may not be discernable or identifiable to the designer due to uncertainties in terms of construction means and methods; however, it may be possible to identify some temporary outfalls during the design process such as outlets to proposed dewatering structures, sediment basin outlets, and at some proposed filter bag locations.

Outfalls may be subdivided so the drainage area to each sub-outfall is below the sediment basin or sediment trap drainage area threshold, and to allow drainage from undisturbed offsite areas ("run-on" water) to pass through a pipe, culvert, ditch, or channel without having to be treated.

See Figures 10-11 and 10-12 for examples of outfall labeling on project plans.

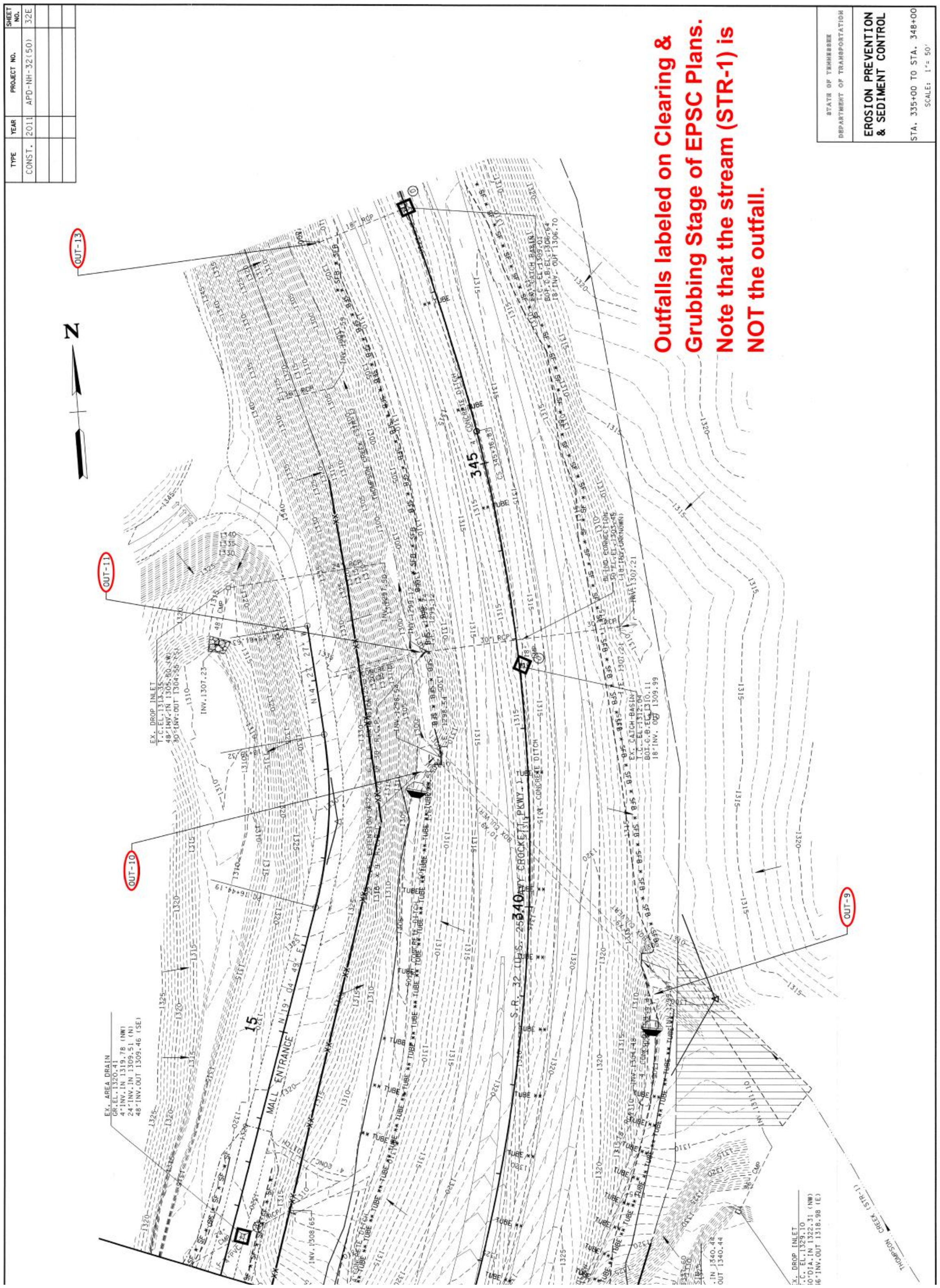


Figure 10-11
Examples of Outfall Labeling for EPSC Plan Sheets

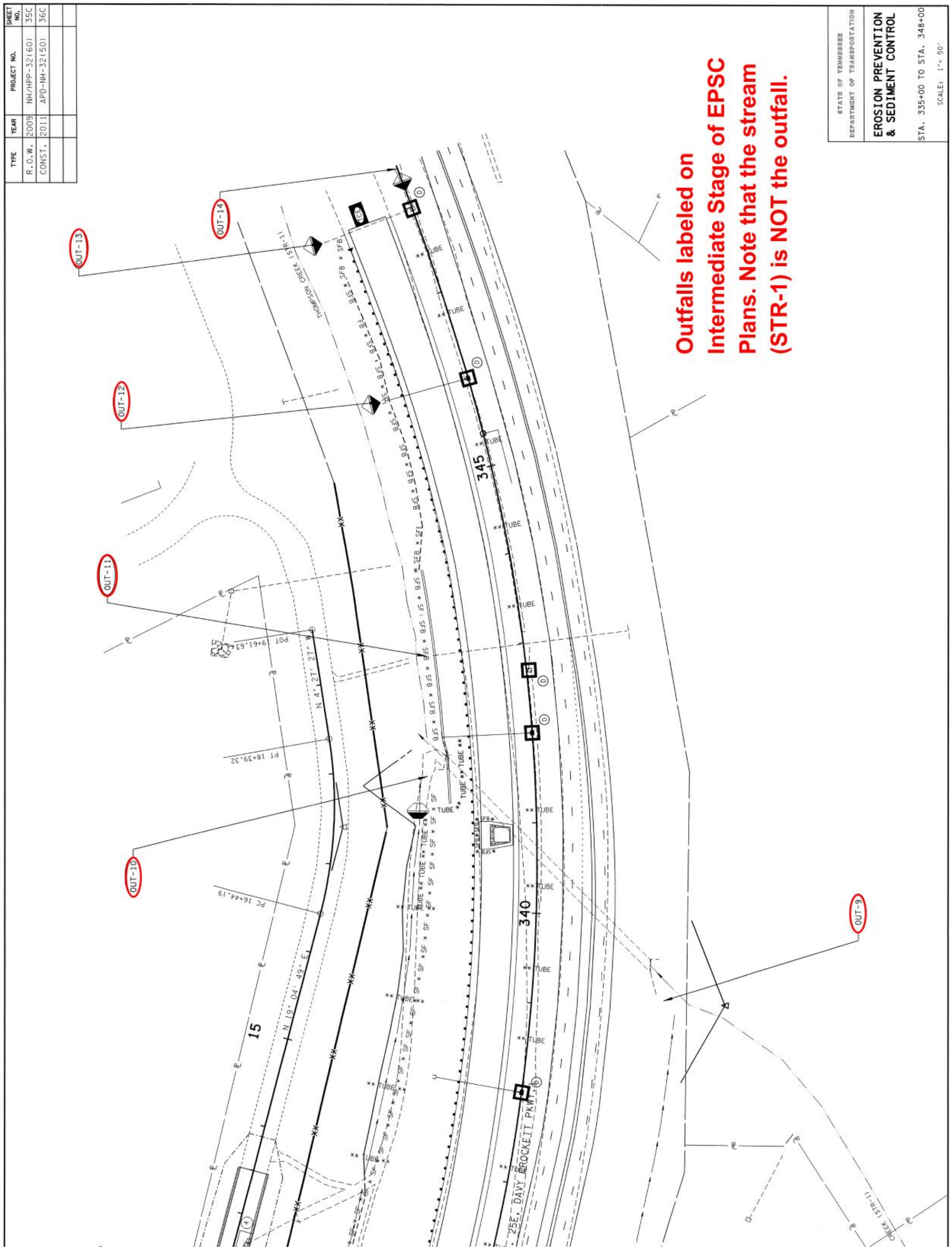


Figure 10-12
Examples of Outfall Labeling for EPSC Plan Sheets

SECTION 10.06 – STAGING OF EPSC PLANS

As a construction project progresses, the conditions on the site and types of activity taking place can change quite significantly. Thus, erosion prevention and sediment control measures which are effective during the early parts of the project may not be appropriate or effective in the later stages of construction. As a result, EPSC plans should be broken into stages to ensure that they will be effective. Staging the EPSC plan may be defined as specifying different sets of structural BMPs to address the changing erosion prevention and sediment control needs of a project as it progresses.

It is important to note that staging an EPSC plan is not the same thing as phasing the project. For the purposes of erosion prevention on TDOT projects, phasing the project (e.g. project phase or phase of construction) will refer to the practice of dividing a site into sections so that land disturbing activities can be done one section at a time. In this way, the amount of area exposed at any given time can be minimized, thus reducing the potential for erosion. Within each "phase" there will be a minimum of 2 or 3 EPSC stages based on the planned area of disturbance for each stage.

Although the contractor will normally be responsible for determining the need for, and devising a phasing plan based on his plan of operation, the designer should be aware of special instances when a phased clearing plan will be required, and ensure that the appropriate instructions and stages are included in the Special Erosion Prevention and Sediment Control notes and in the EPSC plans, respectively. A plan for phased clearing will be required when requested by the Environmental Division.

10.06.1 NECESSITY OF STAGING

To ensure that erosion prevention and sediment control measures will be effective throughout the construction of a project, a staged EPSC plan will be required for all projects which will result in soil disturbance.

Usually the early stages of a roadway construction project involve the clearing and grubbing of vegetation and rough grading. Since it is not always practical to install erosion or sediment controls on the site during these operations, the measures which may be used at that time will principally be perimeter controls, such as silt fence. Further, since this part of the project often involves extensive re-working of the soil, it is not possible to install erosion prevention measures. Thus, sediment control measures are of primary importance. Once the rough grading has been completed, there will be opportunities for measures to be installed across the entire site. Although perimeter controls and other sediment control measures will continue to be important, the emphasis can shift from sediment controls to temporary and permanent erosion prevention measures, especially vegetative measures such as temporary seeding or sod.

10.06.2 EPSC PLAN STAGES

Controlling sediment during construction depends on the timely installation of appropriate erosion protection and sediment control measures over the duration of the project. Thus, an EPSC plan will be divided into multiple stages, regardless of the size of the project. The minimum number of stages required will be based on the total amount of land disturbance that will occur for a project. The assessment of the disturbed area should include the project construction limits as well as any off-site borrow or disposal sites that are dedicated to the project. The following requirements shall apply:

Less than 5 acres disturbed: Projects which involve less than 5 acres of land disturbance require at least two (2) separate EPSC stages. The first stage should address land clearing and initial major grading operations and may be referred to as the Clearing and Grubbing Stage. The second stage should encompass construction of the project and final grading, and would be applied once the ground contours have been altered by the rough and final grading process. This second stage may be referred to as the Final Construction Stage. Both EPSC stages should be developed based on the conditions present and the EPSC devices necessary to minimize erosion and control sediment. The two stages of an EPSC plan for a site less than 5 acres shall be:

- Clearing and Grubbing Stage
- Final Construction Stage

Five (5) or more acres disturbed: Projects which involve the disturbance of 5 or more acres of land will be developed with a minimum of three (3) EPSC stages. At a minimum, the three stages of the EPSC plan should include the following stages:

- Clearing and Grubbing Stage
- Intermediate Grading Stage
- Final Construction Stage

Each stage of the EPSC plan will require a separate set of plan sheets. However, the plans for each stage may refer to a common set of detail sheets. Additionally, it should be noted that many EPSC devices may be shown (and used) during more than one stage of the EPSC plan for the project. Items such as silt fence may be shown on all stages, and many times at the same location on each stage.

Although not a design issue, the designer should keep in mind that not all areas of a project need to be in the same stage of the ESPC plan at the same time. A contractor's staging plan may call for rough grading to be complete in one portion of the project before clearing and grubbing is even started in another portion. Thus, the intermediate grading stage of the EPSC plan may be applied to one area while another project area is still under the clearing and grubbing stage of the EPSC plan.

Additional stages may be added to the ESPC plan to address unusual conditions which affect the entire length of the project. An example of this could include a project for which grading must be done in two parts to accommodate the traffic control plan. Further, it is possible to include "sub-stages" into the EPSC plan to address the needs at specific locations in the project. Examples of this could be the construction of a box culvert during clearing and grubbing operations, or the relocation of a section of railroad. See Section 10.06.2.4.

Staged construction (e.g. Staging Plan) generally should not be addressed in the EPSC plans by the designer unless special project requirements or conditions exist and are known at the time of plan preparation. The contractor will be responsible for devising a Staging Plan based on the staged EPSC plans provided with the project documents when the total project disturbance exceeds 50 acres or where certain site constraints limit the ability of the project to be constructed at one time. The purpose of the Staging Plan is to ensure that no more than 50 acres of land are disturbed at any given time during the construction of the project. The designer should be aware of when a staged plan might be required, and should ensure that appropriate instructions are included in the Special Erosion Prevention and Sediment Control Notes. It should be emphasized that the designer will prepare the staged EPSC plans for the entire project; however, it is normally the contractor's responsibility to develop a plan as to how he or she proposes to stage construction at the project site (especially for sites in excess of 50 acres). Staging is generally considered a function of the contractor's means and methods, and will normally not be addressed by the roadway designer.

The following sections discuss the three major EPSC plan stages described above and provide guidelines on selecting BMPs based on the work being performed.

10.06.2.1 CLEARING AND GRUBBING STAGE

The clearing and grubbing stage of the EPSC plan should show all of the BMPs that are necessary during clearing and grubbing operations at the site. The main objectives during this stage are to divert off-site runoff around the construction site, protect existing features and outfalls, establish perimeter control, and to control sediment that may have been eroded from exposed areas from leaving the site. The clearing and grubbing stage of the EPSC plans should address pre-disturbance BMP installation necessary for pending land grading operations, protection of existing water resources and off site property, protection of existing culverts, inlets, and storm sewers, and items such as construction site entrance/exit points. Thus, the measures required for this stage should be in place prior to starting other construction activities and should always include perimeter controls such as silt fence and stabilized construction exits. Some EPSC measures commonly shown in this stage of the plan include:

- silt fence and silt fence with wire backing
- inlet protection for existing storm sewers and culverts
- sediment basins with floating outlet devices
- temporary diversion berms
- enhanced rock check dams and rock sediment dams
- temporary construction exits
- temporary stream crossings

Section 10.05.3.2 provides a comprehensive list of existing and proposed site features which should be shown on the site plan sheets of an EPSC plan. However, not all of these items should be included in the clearing and grubbing stage of the plan. Specifically, there are two main types of items which should be **excluded** from this stage of the plan. First, any permanent EPSC measures should not be included in this stage of the plan. A sediment basin which will later be used as permanent detention for the project may be shown in both stages; however, performance notes should also be provided to describe the conversion of the basin from a temporary to permanent status. Second, a number of elements to be constructed during the later construction stages of the project should not be shown for this stage. These elements include side drains, side drain end sections, driveway and road approaches, stream relocations and flow direction arrows for special ditches. All of the other items listed in Section 10.05.3.2 should be included in the plan sheets for this stage.

10.06.2.2 INTERMEDIATE GRADING STAGE

The intermediate grading stage of the EPSC plans should include those devices needed during the mass grading of the site, and should also include temporary measures used during the construction of site features such as bridges, storm sewers and inlets, cross drains, box culverts, and utilities. At this point in the project, some outfall locations may change, new outfalls may be created, and some existing outfalls may be removed. All of these changes require additional EPSC measures to be shown for the changing conditions. Mass grading is occurring on site, and thus significant changes to the original topography and on-site flow patterns should be expected. In addition to many of the devices previously shown on the clearing and grubbing stage, the following are some EPSC measures commonly shown on the intermediate grading stage of an EPSC plan:

- dewatering structures and sediment bags
- diversion channels, berms, and culverts
- rock check dams and enhanced rock check dams
- sediment traps
- culvert protection
- in-stream diversions
- suspended pipe diversions
- turbidity curtains
- catchbasin filter assemblies

The designer should note that site conditions during this stage are changing rapidly on a typical active project. Many of the measures to be used and shown as part of the intermediate stage of the EPSC plans are truly “temporary” and may be used for very brief periods of time such as during bridge construction as in the case of a turbidity curtain. Perimeter controls previously shown on the clearing and grubbing stage (i.e. silt fence) are considered pertinent to this stage and should also be shown on this stage of the EPSC plans.

10.06.2.3 FINAL CONSTRUCTION STAGE

The final construction stage of the EPSC plan should include the measures needed from the intermediate grading stage to the final completion of the project. Usually, major grading will be complete or nearly complete by this time and the project is close to final grades and contours. The erosion prevention and sediment control measures provided in this stage should be designed to accommodate the final proposed site topography. The final construction stage should address final grading, shaping, and topsoil operations, base stone and paving, final stabilization of slopes and ditches, and construction of permanent features such as detention basins and riprap outlet protection.

As with the other stages, the objectives of this stage of the plan include diverting off-site water around exposed areas and preventing eroded sediments from escaping the site. However, in this stage, the emphasis shifts to holding the soil in place across the site. Thus, in addition to placing measures around the perimeter of the site, it is possible to specify measures which can be used anywhere on the site. The designer should ensure that any planned permanent erosion prevention and sediment control measures are clearly shown in this stage of the plan. Section 10.08 presents the standard erosion prevention and sediment control measures which may be utilized on a TDOT project.

In addition to many of the devices previously shown on the clearing and grubbing stage and/or the intermediate grading stage, the following are some EPSC measures commonly shown on the final construction stage of an EPSC plan:

- filter socks and sediment tubes
- catch basin protection (Types A through E)
- rock check dams and enhanced rock check dams
- riprap basin energy dissipators and riprap outlet protection
- culvert protection
- slope drains and berms
- erosion control blankets and TRMs
- curb inlet protection (Types 1 though 4)
- level spreaders

Some of the EPSC plan elements listed in Section 10.05.3.2 are needed only for the clearing and grubbing stage of the plan and should not be shown in the final construction stage. Since the final construction stage of the plan is primarily concerned with the proposed construction, existing site features such as houses, fences, etc., do not need to be shown. Further, since the site topography has likely been significantly altered, the existing elevation contours do not need to be shown. Permanent seeding, sod in ditch flow lines and other vegetative measures called for in the TDOT Standard Drawings or Standard Specifications also should not be shown. However, erosion control blankets on slopes or specialized vegetative ditch linings should be shown where they are required. All of the other items listed in Section 10.05.3.2 should be included on the plan sheets for this stage, as needed.

10.06.2.4 SUBSTAGES

The need to include a sub-stage in an ESPC plan should be determined on a case-by-case basis, based on the specific conditions presented by the project. Usually, a sub-stage would be needed to accommodate the construction of specialized features within the larger project, such as box bridges, retaining walls or utility work included in the project. The Traffic Control Plan should also be carefully considered when determining the need for a sub-stage.

The EPSC plan sheets for a sub-stage should be placed in the plan set following the sheets for the main stage to which it pertains. For example, the sheets showing the EPSC measures for a box bridge to be constructed as a part of the rough grading operations should be inserted into the plans following the clearing and grubbing EPSC plan sheets. In general, the specific items to be shown on the sheets for a sub-stage should be the same as the list of items to be shown on the sheets for the corresponding main stage, as described in Section 10.05.3.2.

SECTION 10.07 – ACCEPTABLE SOFTWARE

Computer applications for soil erosion prevention and sediment control design are described in this section. These software packages assist the designer in determining an effective erosion prevention and sediment control plan by providing estimates of the amount of soil loss which would occur at a given site. The Tennessee Department of Transportation does not encourage or endorse the use of any specific software package. At this time RUSLE2 and WEPP are the most widely recognized software tools available for estimating sediment loads. When projects involve particularly sensitive waters (Exceptional Tennessee Waters, sediment-impaired waters, etc.) or habitat, these programs may be considered valuable tools for addressing how decisions will be made regarding appropriate BMPs and how they will be maintained.

10.07.1 RUSLE2

RUSLE2 is an easy to use computer application designed to compute average-annual erosion by water. Development of this program was a joint project involving the USDA-Agricultural Research Service (ARS), the USDA-Natural Resources Conservation Service (NRCS), and the University of Tennessee. RUSLE2 is an enhanced Windows™ version of the original DOS program RUSLE 1.06 and is available on the Agricultural Research Service website of the NRCS.

RUSLE2 estimates annual average soil erosion caused by rainfall and the associated overland flow on a site. It uses four major factors to compute erosion estimates; including climate, soil type, topography, and land use. The program also uses the conservation of mass and transport capacity principles, along with the universal soil loss equation, to estimate both erosion and deposition. An example of a typical analysis using RUSLE2 is provided in the Appendix.

10.07.2 WEPP

WEPP (the Water Erosion Prediction Project) is a continuous simulation erosion prediction model designed by the USDA to compute detachment and deposition for sheets and rills as well as for channels, and is readily available in a Windows™ based version. The software was designed by USDA-Agricultural Research Service (ARS) and Purdue University at the National Soil Erosion Research Laboratory. The program simulates a number of years with each day having a different set of climatic conditions. On each simulation day, a rainstorm may occur, which may or may not cause a runoff event. If runoff is predicted to occur, the soil loss on the site, sediment deposition, and sediment loss off-site will be calculated. This value can then be divided by a time interval which allows erosion to be predicted on a daily basis. The program allows users to simulate runoff, erosion, and sediment delivery from entire watersheds (up to 2000 acres) or portions of the watershed. Additionally, the program allows the user to compare management practices under different scenarios.

The WEPP erosion model simulates the following erosion processes:

- detachment and transport by raindrop impact
- detachment, transport, and deposition by overland rill flow
- detachment, transport, and deposition by concentrated channel flow

- deposition by impoundments

Factors used to calculate these processes include rill erosion and inter-rill erosion (caused by raindrop impact and splash), sediment transport, sediment deposition, surface sealing, rill hydraulics, surface runoff, plant growth, evaporation, transpiration, snow melt, frozen soil effects, and soil roughness, among others. WEPP takes into account both spatial and temporal variability in topography, surface roughness, soil properties, and land use conditions of hill-slopes. Almost all of these factors used for hill-slopes are duplicated for concentrated channel flow. Impoundments such as check dams, culverts, and silt fences can be simulated and evaluated to remove sediment from the flow.

The WEPP model is an evolving tool which requires input data at the watershed level. This data is seldom available for rural highways which may cross several watersheds within the limits of a single project. However, with continued development of detailed GIS systems by federal, state, and local agencies, this data may become more readily available over time. Until then, WEPP remains a tool of limited use in most transportation applications.

10.07.3 EGEM VERSION 2.0

Ephemeral Gully Erosion Model is a DOS-based computer application designed to compute gully erosion. EGEM is under development by the Hydrology Unit of NRCS at NHQ in Washington D.C. This software can estimate gully erosion for a single storm or average annual conditions. It also provides estimates of the width, depth, and area voided by an ephemeral gully.

10.07.4 TMDL USLE

Total Maximum Daily Load (TMDL) Universal Soil Loss Equation (USLE) model is a Windows-based software application used for estimating the expected relative magnitude of land surface sediment loading from different land use types within a watershed. Although the primary function of the software is to estimate sediment loadings generated by erosion on agriculture lands, it can also be applied to construction sites and landfills. However, the software does not consider the effects of in-stream processes such as bank erosion and bed scour or deposition.

The user interface of this program is similar to a spreadsheet. The spreadsheet tool provides assistance to the user in determining the information which should be input to the model. However, the amount of that assistance varies from factor to factor. Certain factors, such as the cover-management factor “C” are complex and locally variable. Thus, only limited guidance can be provided by a program which is national in scope. In such cases the user will need to perform off-line investigations to select an appropriate value for their particular study area.

SECTION 10.08 – GUIDELINES AND CRITERIA FOR EPSC MEASURES

This section contains guidelines and criteria for applying erosion prevention and sediment control best management practices on a construction site. Each section includes the following information:

- Definition and Purpose
- Appropriate Application
- Limitations
- Planning and Design Criteria
- Example Application

The example application provides a brief example of applying the BMP and calculating quantities for each of its pay items.

The BMPs in this section are arranged by their primary function, and then by the numerical order of their corresponding Standard Drawings. Following these are the BMPs which are not shown on standard drawings, arranged in alphabetical order. Figures 10A-2 through 10A-4, "Functional Classification of Control Measures Flow Chart", are located in the Appendix of this chapter and serve to classify each of the measures discussed in this section and to provide guidance on where they may be used. The primary functional classifications are:

- Erosion Prevention Measures
- Sediment Control Measures
- Flow Control Measures

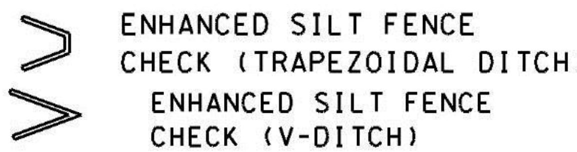
10.08.1 EROSION PREVENTION MEASURES

Erosion prevention best management practices are the primary weapon in the designer's arsenal of tools to prevent pollution caused by sediment released from a construction site. The purpose of these measures is to prevent soils from being dislodged and subsequently transported from their original location. Because no measure is 100% effective at eliminating erosion, measures to control sedimentation are used to capture sediments which have been dislodged and prevent them from leaving the site. However, effective use of erosion prevention measures can significantly reduce the stress placed on sedimentation measures, thus reducing the overall cost of implementing the Erosion Prevention and Sediment Control Plan. Erosion prevention measures work by:

- slowing flow velocities to prevent the dislodging and transport of sediments in channels or other conveyance systems
- covering exposed areas to prevent damage by construction vehicles or erosion caused by rain, wind, or other factors
- diverting concentrated stormwater runoff from potentially erodible exposed soils

This section describes several best management practices which may be used in TDOT projects. It also provides guidelines on where and how to apply these practices. Where steep slopes or very fine soils are present, additional chemical (i.e. polyacrylamide, etc…) or physical treatment may be needed prior to the stormwater leaving the project site.

10.08.1.1 ENHANCED SILT FENCE CHECK (EC-STR-4, 4A, AND 4B)



Enhanced Silt Fence Check
Location: I-40, Smith County, TN (2005)

10.08.1.1.1 DEFINITION AND PURPOSE

This BMP consists of an enhanced silt fence constructed in an angled arrangement across a small swale, drainage ditch or area of concentrated flow. The silt fence is supported by steel posts driven 3.5 feet into the ground and placed at 2 foot centers. The woven monofilament geotextile fabric used for the fence is reinforced with a metal wire backing.

The purpose of the enhanced silt fence check is to remove suspended sediments from stormwater flow via settling (the primary mechanism) and flow-through filtration (the secondary mechanism). In addition, enhanced silt fence checks serve to prevent erosion on the surface of a swale, ditch, or other conveyance by reducing the stormwater flow velocity. This measure is intended to be an enhanced alternative to the standard rock check dam. While both the rock check dam and the enhanced silt fence check reduce velocities, the enhanced silt fence check improves Total Suspended Solids (TSS) removal as much as 67% to 114% over the TSS removal achieved by a standard rock check dam (Barrett, et al., 1995).

Due to the enhanced silt fence check's application in a concentrated flow environment, its fabric material must be able to withstand greater hydrostatic and puncture forces than standard woven slit-film silt fence. Thus, the woven monofilament geotextile used in an enhanced silt fence offers far greater tensile, burst, and puncture strength than a traditional silt fence. The material used in enhanced silt fence also offers as much as 8 times more capacity to pass flow than standard slit-film silt fence fabric. It offers this flow capacity with apparent opening sizes equal to or, in some cases, finer than the opening sizes of standard silt fence.

10.08.1.1.2 APPROPRIATE APPLICATIONS

This measure may be applied in small open channels conveying stormwater flow, not to exceed the maximum allowable design peak flows defined in the "Limits of Flow" tables on the standard drawings. Enhanced silt fence checks should not be used in any waterways designated as ephemeral, intermittent, or perennial streams. Specific applications include:

- temporary or permanent swales or ditches collecting runoff from a watershed that is not stabilized against erosion, where the suspended solids load is expected to be high;

- temporary or permanent swales or ditches collecting runoff from a watershed that subsequently drain to listed Exceptional Tennessee Waters or sediment-impaired streams, where the watershed is not stabilized against erosion;

- temporary or permanent swales or ditches in need of protection during establishment of grass linings;

- temporary or permanent swales or ditches which, due to their short length of service or for other reasons, cannot receive a non-erodible lining; and

- other locations where small localized erosion and resulting sedimentation problems can occur.

As a structural system, enhanced silt fence is designed to be durable under the hydraulic stresses of the concentrated flow environment. It utilizes a high-strength geotextile fabric, as discussed above, which is placed on posts spaced at 2 feet intervals and embedded into the ground at least 3.5 feet. Thus, this measure can withstand the stresses encountered under high flow conditions. Field observations have also confirmed the durability of this measure, even when overtopping occurs.

10.08.1.1.3 LIMITATIONS

The effectiveness of this BMP may be reduced when the fence is bypassed or overtopped during heavy rain events.

10.08.1.1.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is required in that the hydrologic and hydraulic analysis of the waterway is necessary in order to determine the length of enhanced silt fence required for each enhanced silt fence check, to determine an appropriate overflow weir length, and if widened zones are necessary for each enhanced silt fence check.

For every enhanced silt fence check, the following information shall be provided in the EPSC Plans. The dimensions of the enhanced silt fence check L, X1, and X2 as shown on the standard drawing, length of overflow weir, the total length of enhance silt fence, the bottom width of the widened zone, the length of the widened zone, the transition ratio to and from the widened zone, the length of the transitions should be placed in the EPSC Plans as shown in Table 10EP-1.

Station (LT or RT)	L (ft)	X1 (ft)	X2 (ft)	Overflow Weir Length (ft)	Total Length of ESF (ft)	Widened Zone				
						Bottom Width (ft)	Side Slope (H:1)	Length (ft)	Transition	
									Ratio	Length (ft)

Table 10EP-1
Data Required on EPSC Plans for Enhanced Silt Fence Check

In general, the peak flow rate generated by the design storm specified in Section 10.05.1 should pass through the enhanced silt fence fabric at an upstream depth of no more than 18 inches. The "Limits of Flow" table on Standard Drawing EC-STR-4 provides the maximum allowable peak design flows which will meet the criteria for trapezoidal ditches of varying sizes, and "Limits of Flow" table on Standard Drawing EC-STR-4A provides the maximum allowable peak design flows which will meet the criteria for V-ditches with varying side slopes.

It is imperative to install the enhanced silt fence check in an angled pattern as shown in the standard drawings. This arrangement is required to provide an adequate surface area to convey the BMP design flow through the fence fabric. This arrangement also increases the available length for the overflow weir. It is also important to ensure that the total length of the fence adheres to the specifications shown on the standard drawings in order to prevent unwanted bypassing of flow around the ends of the fence.

The maximum spacing between enhanced silt fence checks should be as described in the standard drawings. This spacing is based upon a maximum allowable depth of 18 inches upstream of the fence before overflow occurs.

The side slopes of the ditch should be 2H:1V or flatter.

As discussed in the Example Application, the "most critical point" in a waterway to be protected by enhanced silt fence check is at the downstream end of the project. This is the point at which the drainage area contributing flows to the ditch is the greatest. Flows beyond this point will either flow off-site through the waterway or be discharged into a stream, pond, lake, or wetland.

It is important to note that not all ditches will be able to accommodate an enhanced silt fence check at the critical point. Where the watershed is sufficiently large that the 2-year (5-year for Exceptional Tennessee Waters or sediment-impaired waters) flow exceeds the values provided on the standard drawings an alternate measure such as an enhanced rock check dam should be employed. However, it may be possible to place enhanced silt fence checks in the upper reaches of the watershed where they can accommodate the BMP design flow.

In general, the location and sizing of enhanced silt fence checks will be determined in conjunction with the design of the ditches which they serve. Typically, the dimensions of the waterway are determined based upon the ditch design storm, usually the 10-year or the 50-year event. However, this sizing should be deemed preliminary until the enhanced silt fence check size has been determined as described above. Often, the design flow rate for the enhanced silt fence check will be sufficiently great that the trapezoidal bottom width determined based on “Limits of Flow” table on EC-STR-4 will be larger than the bottom width required to convey the 10-year or 50-year ditch design flow. Where this is the case, two alternatives are possible. The first is to increase the width of the ditch throughout its entire length to the size determined for the enhanced silt fence check. However, this alternative may not be economical. The second alternative is to widen the ditch bottom to the required bottom width only in the vicinity of the enhanced silt fence check, as shown in Figure 10EP-1. When the enhanced silt fence check is removed at the conclusion of the project, the waterway should be re-graded to a consistent cross section.

The “Maximum Allowable Peak Flow” given in the tables on the standard drawings are based on the application of Darcy’s Law using clean water. However, in the field, suspended solids in the flow will accumulate on the surface of the enhanced silt fence over time and decrease its hydraulic capacity. The rate of solids accumulation and the degree of clogging will depend upon the gradation and quantity of suspended sediments produced in the watershed, which will vary from site to site and also as construction conditions change during the project. Because of this, it is difficult to apply a single clogging factor to the hydraulic capacities provided in the standard drawing. Thus, one of the vital functions of the overflow weir is to allow for emergency bypass when the fence becomes excessively clogged.

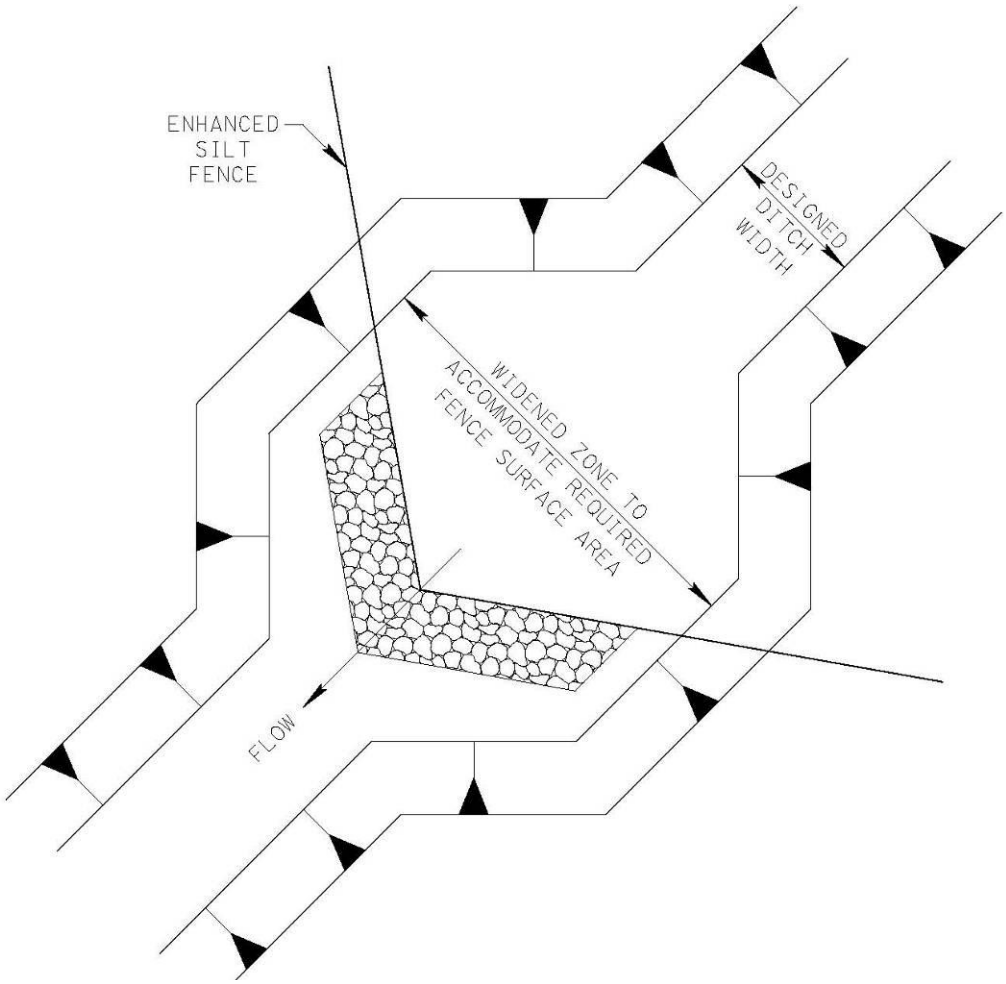


Figure 10EP-1
Plan View: Ditch Cross Section Widened to Accommodate
the Required Length of Enhanced Silt Fence Check

The overflow weir should be sized to accommodate the peak ditch design flow (i.e. – the 10-year or 50-year discharge); using the worst-case assumption that the enhanced silt fence check becomes completely clogged during the storm event. The length of the weir should be determined using the sharp-crested weir equation (Equation 8-22) presented in Section 8.05. The weir length should be sufficient to ensure that adequate freeboard will be provided between the upstream depth and the top of the fence for the ditch design flow rate. Usually, 12 inches of freeboard should be allowed, which represents an upstream depth of 28 inches, provided that this depth will not overtop the ditch. The allowable upstream depth should be reduced where the height of the ditch banks is less than 28 inches. It should also be noted that each end of the weir must terminate at a fence post. Thus, the weir length determined by the weir equation should be rounded up to the next 2 feet.

The designer should provide riprap on the channel bed immediately downstream of an enhanced silt fence check to protect the bed from scour due to flows over the overflow weir.

This riprap should be inset into the bed of the waterway in order to maintain an open flow path through the enhanced silt fence check. It should also extend along the front of the overflow weir.

Although it is not strictly a design issue, the designer should bear in mind that enhanced silt fence checks require regular maintenance and cleaning. Field observations have indicated that an enhanced silt fence check is somewhat "self-cleaning" if it is located in an area where rainfall will fall onto the fence unimpeded. Since the fence material consists of a woven monofilament, any retained sediments are often readily removed during the onset of rainfall, prior to runoff production. Thus, if the enhanced silt fence check is located under a heavy vegetative canopy, manual cleaning of the fence may be required. In that case, residual sediments on the surface of the fence can be removed by brushing and/ or pressure washing.

Enhanced silt fence checks should be removed at the competition of its useful life, along with any riprap placed on the downstream side of the fence. After removal, the area beneath the enhanced silt fence check location should be immediately seeded and covered with a rolled erosion control product to provide mulch coverage and erosion prevention.

An enhanced silt fence check should be constructed per the details and specifications provided in the following standard drawings:

- EC-STR-3D Enhanced Silt Fence
- EC-STR-3E Erosion Control Fabric Joining Details
- EC-STR-4 Enhanced Silt Fence Check (Trapezoidal Ditch)
- EC-STR-4A Enhanced Silt Fence Check (V-Ditch)
- EC-STR-4B Enhanced Silt Fence Check Details

Enhanced silt fence ditch checks should be paid for under the following item numbers:

- 209-05, Sediment Removal, per CY
- 209-08.05, Enhanced Silt Fence Check (V-Ditch), per Each
- 209-08.06, Enhanced Silt Fence Check (Trapezoidal), per Each

10.08.1.1.5 EXAMPLE APPLICATION

Given: The Department is designing a roadway project for an arterial roadway through a watershed where enhanced silt fence is to be used to control erosion along the main channel. The characteristics of this watershed are as follows:

- Drainage Area: 10 acres
- Location: Northern Davidson County
- Overall time of concentration: 10 minutes
- Rational Method Runoff Coefficient: 0.8 (newly graded Type C soils)
- Length of the proposed drainage ditch: 450 ft.
- Ditch slope: 1.0%
- The ditch will be trapezoidal with 4H:1V side slopes
- The ditch will be provided with a grassed lining

The overall watershed is depicted in Figure 10EP-2.

Find: Determine the required ditch cross section dimensions, as well as the locations and dimensions of the proposed enhanced silt fence checks.

Solution:

Step 1: Determine design storm frequencies: As specified in Table 4-1 of this Manual, the 10-year storm is to be used to design the dimensions of the ditch. Because no special regulatory requirements exist at this site, the 2-year 24-hour storm will be used to design the erosion prevention and sediment control measures.

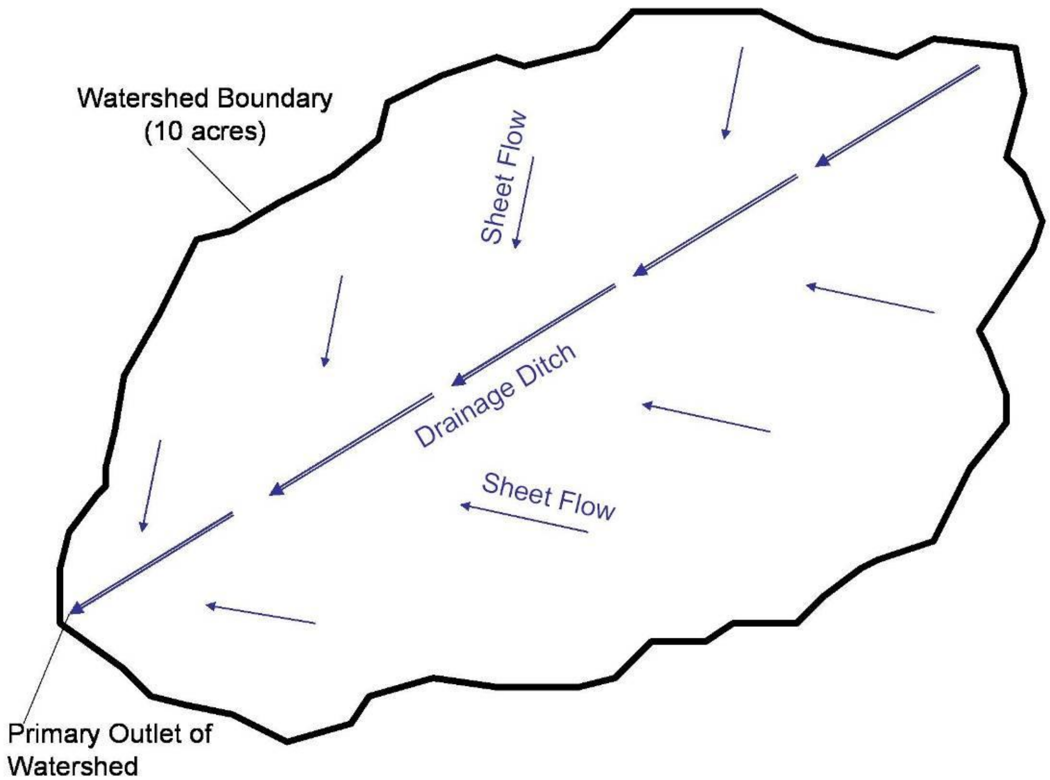


Figure 10EP-2
Overall Watershed (not to scale)

Step 2: Determine the number and locations of the enhanced silt fence checks: Before determining the number of enhanced silt fence checks, it is necessary to locate the most critical point(s) in the watershed. Usually, the critical point will be the lowest point of the watershed within the project area, unless the channel passes through a pond, lake, or wetland. Since the peak flow from the entire watershed must pass through the critical point, an ESF check will automatically be placed at this location. Since no wetlands or similar features exist in the watershed, the only critical point is at the outlet, and an ESF check is placed at that location as shown in Figure 10EP-3.

The locations for the ESF checks above the critical point can be selected in a number of ways. The simplest way is to divide the total length of the ditch into equal segments. Thus, if "n" is the number of ESF checks to be installed, the ditch is to be divided into n equal lengths.

Another approach may be to place the ESF checks immediately downstream of influent points along the ditch where turbid water is expected to enter. In this example, it is deemed sufficient to simply divide the channel into equal segments.

As shown in the recommended spacing table on EC-STR-4, a spacing of 150 feet should be used for a ditch slope of 1.0%. Since the proposed ditch length is 450 feet, the total number of ESF checks required would be 450 feet/150 feet = 3 ESF checks. ESF check 1 would be located at the outlet of the 10-acre watershed, ESF check 2 would be located 150 feet upstream of the outlet and ESF check 3 would be located 300 feet upstream of the outlet.

Step 3: Design the ditch cross section and enhanced silt fence check at the critical point: As shown in Figure 10EP-3, the first enhanced silt fence check to be designed will be at the critical point of the watershed. As discussed in the Planning and Design Criteria, the design of this ESF check will be conducted together with the design of the ditch cross section.

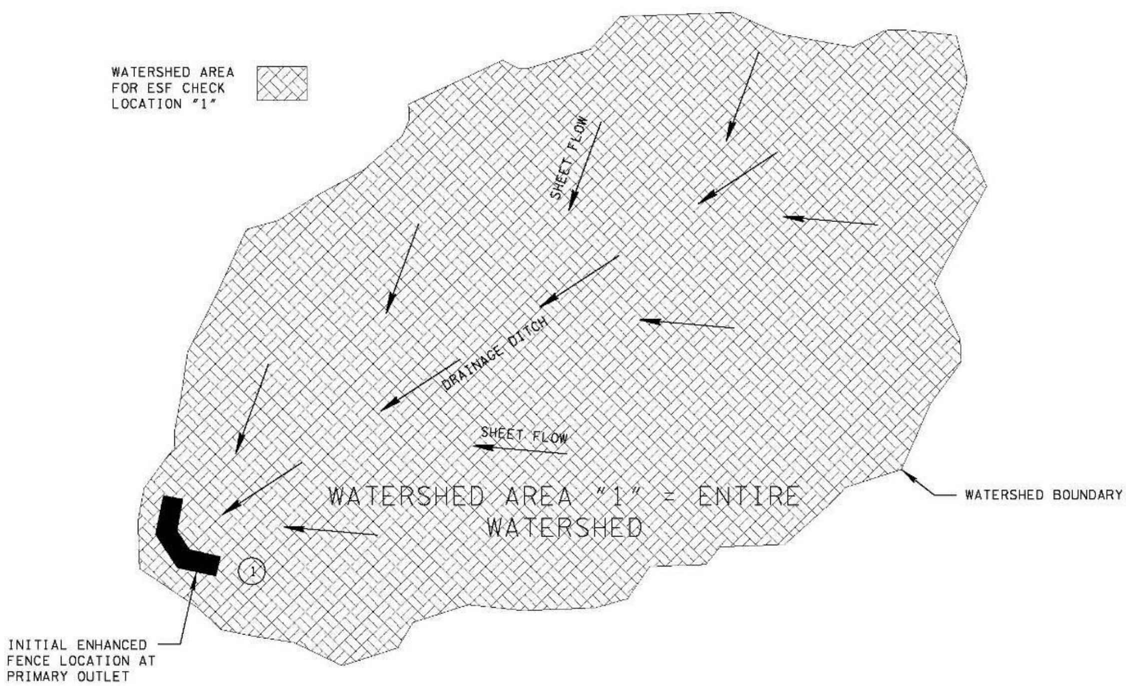


Figure 10EP-3
Critical Point Location and First Enhanced Silt Fence Check (not to scale)

The first part of this step is to determine the flow rates to be used for the design. The hydrologic design will involve two different design storm events: 10-year ditch design flow, and the 2-year, 24- hour BMP design flow. The hydrologic parameters for this site are provided in the “Given” statement above. Because the drainage area at the critical point is 10 acres, the Rational Method is used to determine these design flow rates. Since the site is located in northern Davidson County, the Lebanon IDF Curves presented in Figure 4A-9 are used to determine rainfall intensities of 5.6 in/hr and 4.4 in/hr, respectively, for the 10-year and 2-year events. Thus, the 10-year design discharge may be computed as:

$$Q_{10} = C\,i_{10}\,A = (0.8)(5.6)(10) = 44.8 \text{ cfs}$$

In the same manner, the 2-year discharge is found to be 35.2 cfs.

The second part of this step is to determine preliminary dimensions for the proposed channel. As noted above, the dimensions determined in this part must be re-evaluated once the design of the ESF check has been determined. Based upon site conditions, it is determined that the ditch at this location should be 3 feet deep from the top of bank to the flow line. As described in Chapter 5, 1 foot of freeboard will be required at the ditch design flow rate so that the greatest allowable depth of flow will be 2.0 feet. Based upon an analysis of a trapezoidal cross section with 4H:1V side slopes, it is determined that a depth of 2.0 feet would result in a hydraulic radius of roughly 1.0. Based upon table 5A-10, this corresponds to a Manning's n-value of 0.07. Using Manning's Equation, it is determined by trial and error that a ditch bottom width of about 2 feet would be required to convey the 10-year flow rate of 44.8 cfs at a depth of 2.0 feet or less. However, since the minimum bottom width is 4 feet, this is selected as the preliminary ditch bottom width.

The third part of this step is to determine the dimensions of the proposed enhanced silt fence check. Based on "Limits of Flow" table on Standard Drawing EC-STR-4, the total length of fence required on the channel bottom (the dimension "2L" as shown on the drawing) for a flow rate of 35.2 cfs would be 21.2 feet. The dimension "L" is thus 10.6 feet. Once this has been determined, it is necessary to compute the length of the remaining portions of the enhanced silt fence. The dimension X_1, as shown on the drawing, is the fence length from the edge of the channel bottom to a point 1.5 feet above the bottom of the channel. Since the fence is at an angle of 45° to the channel, X_1 will equal to the perpendicular length along the side slope (Y_1 on the drawing), divided by the cosine of 45° (this is equivalent to multiplying by 1.414, as specified on the standard drawing). Since the sides of the channel are at a slope of 4H:1V, Y_1 may be computed as:

$$Y_1 = 4 \times 1.5 = 6.0 \text{ feet}$$

and,

$$X_1 = Y_1 \times 1.414 = 6.0 \times 1.414 = 8.5 \text{ feet}$$

Since the enhanced silt fence is required to extend an extra 6 feet past the point where the channel depth is 1.5 feet, the total length of one side of the ESF check may be computed as:

$$L + X_1 + 6.0 = 10.6 + 8.5 + 6 = 25.1 \text{ feet}$$

Since the maximum spacing for the posts used to install the fence is 2 feet, this result is rounded to 26 feet and the total length of enhanced silt fence required is 52 feet.

Review of "Limits of Flow" table on the standard drawing also shows that the required trapezoidal bottom width for the selected length of fence is 15 feet, which is very much greater than the 4-foot bottom width determined in the second part of this step. Since it is not economically practical to construct the entire segment of the channel with a bottom width of 15 feet, it is decided to widen the channel in the area of the ESF check, as described in the Planning and Design Criteria. This widened area will consist of a section of widened ditch and two transitions. The difference between a 15-foot bottom width and a 4-foot bottom width is 11 feet. Since this transition will be equally split between both sides of the ditch, the width will change by 5.5 feet on each side of the channel. Given a transition ratio of 1:1, a distance of 5.5 feet will be required for each transition. The widened section must be long enough to accommodate the angled length of the ESF check plus the riprap armoring on the downstream side of the fence. The length of half of the fence is 26 feet. Since it is installed at a 45° angle with respect to the ditch flow line, its length along the channel may be computed as:

$$Length = 26 \times cos(45°) = 18.4 \text{ feet}$$

It is assumed that the riprap armor on the downstream side of the fence will be 4 feet long, and an extra foot of length will be allowed on each end of the ESF check. Thus, the total length of the widened section will be 24.4 feet. Combined with the two transitions, the total length of the widened portion of the channel will be 35.5 feet, rounded to the nearest 0.5 feet.

Step 4: Design the ditch cross section and enhanced silt fence check at the second location: As noted in Step 2, ESF check number 2 will be located 150 feet upstream of the watershed outlet point, as shown in Figure 10EP-4. The process used to design the ESF check at this location will be the same as that used in the previous step, and thus the first part is to determine the design flow rates. Since this site is upstream of the watershed outlet, the contributing drainage area will be less and revised hydrologic parameters are as follows:

- Drainage Area: 6.7 acres
- Overall time of concentration: 8.4 minutes

This area is also analyzed using the Rational Method as described above. For the given time of concentration, rainfall intensities of 6.0 in/hr and 4.8 in/hr are found on Figure 4A-9, and flow rates of 25.7 cfs and 32.2 cfs are computed for the 2-year and 10-year storm events, respectively.

Based upon site conditions, it is determined that the channel at this location should be 2.7 feet deep. Since 1 foot of freeboard is required, the allowable depth for the 10-year design flow will be 1.7 feet. As for the first site, Manning’s Equation is used with an n-value of 0.07 to determine that a channel bottom width of 1 foot will provide sufficient conveyance to pass the design flow at the required depth. However, the preliminary channel design will be based upon the minimum bottom width of 4 feet. Once the enhanced silt fence check size has been determined, this bottom width may need to be further adjusted.

The “Limits of Flow” table on Standard Drawing EC-STR-4 indicates that a fence length (dimension “2L” on the standard drawing) of 12.7 feet (thus, “L” = 6.4 feet) is required on the channel bottom for a 2-year flow rate of 25.8 cfs. Since this flow rate is nearly equal to the computed 2-year flow rate of 25.7 cfs, this length of fence will be used on the channel bottom. Following the logic described in step 2, the length of the fence for the first 1.5 feet of depth in the channel (X_1) will be 8.5 feet. Thus, the total length of one side of the ESF check may be computed as:

$$L + X_1 + 6.0 = 6.4 + 8.5 + 6.0 = 20.9 \text{ feet}$$

Since the maximum spacing for the posts used to install the fence is 2 feet, this result is rounded to 22 feet and the total length of enhanced silt fence required is 44 feet.

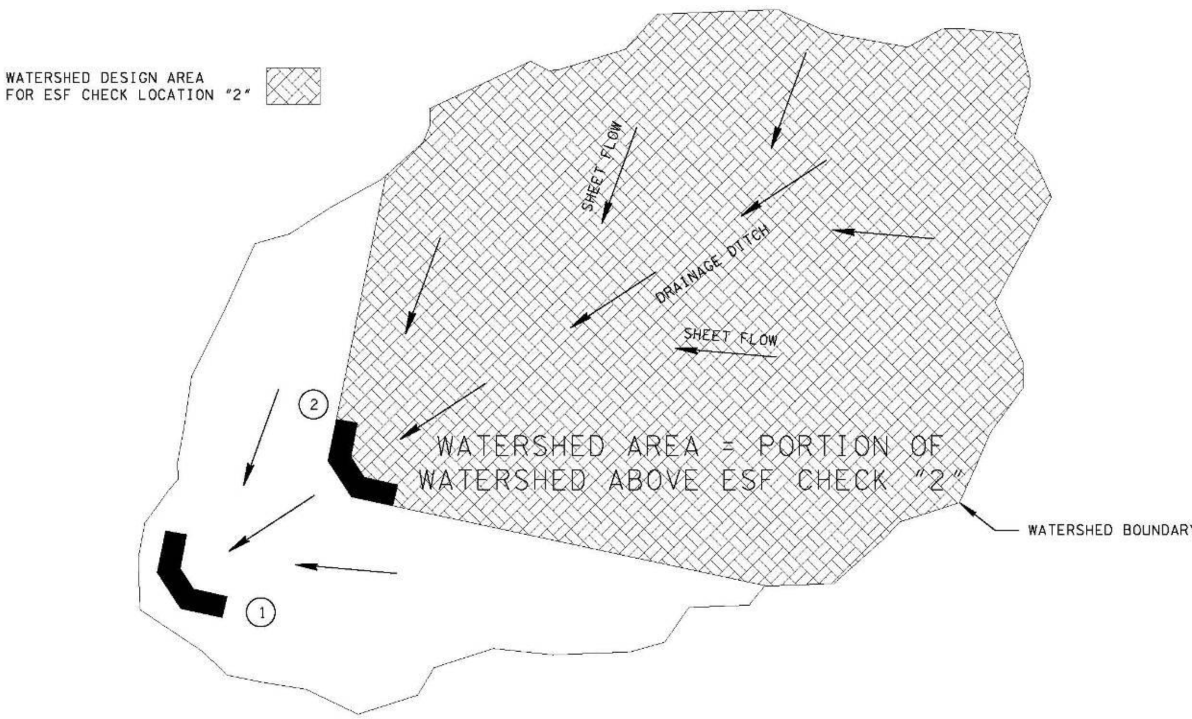


Figure 10EP-4
Location, Enhanced Silt Fence Check Number 2 (not to scale)

The table also indicates that a channel bottom width of 9 feet will be required for the ESF check. Since the channel bottom width both upstream and downstream of the ESF check location needs to be only 4 feet it is decided to widen the channel at this ESF check location. In order to transition from a 4-foot bottom width to a 9-foot bottom width, an adjustment of 2.5 feet will be necessary on both sides of the channel. Since the transitions will be at a 1:1 ratio, the combined length of the two transitions will be 5 feet. Again using the same logic as described in Step 3, the length of the enhanced silt fence with respect to the channel bottom may be computed as:

$$Length = 22 \times cos(45°) = 15.6 \text{ feet}$$

Allowing 4 feet for riprap armor on the downstream side of the ESF check, along with an additional foot on each end of the ESF check yields a total length of 21.6 feet for the widened section of the ditch. With the two transitions, the length of the widened section of the ditch will be 27 feet (rounded to the nearest 0.5 feet).

Step 5: Design the ditch cross section and enhanced silt fence check at the third location: As noted in Step 2, ESF check number 3 will be located 300 feet upstream of the watershed outlet point, as shown in Figure 10EP-5. The process used to design the ESF check at this location will be the same as that used at the previous two locations, and thus the first part is to determine the design flow rates. Since this site is further upstream, the contributing drainage area will be less and revised hydrologic parameters are as follows:

- Drainage Area: 3.3 acres
- Overall time of concentration: 6.7 minutes

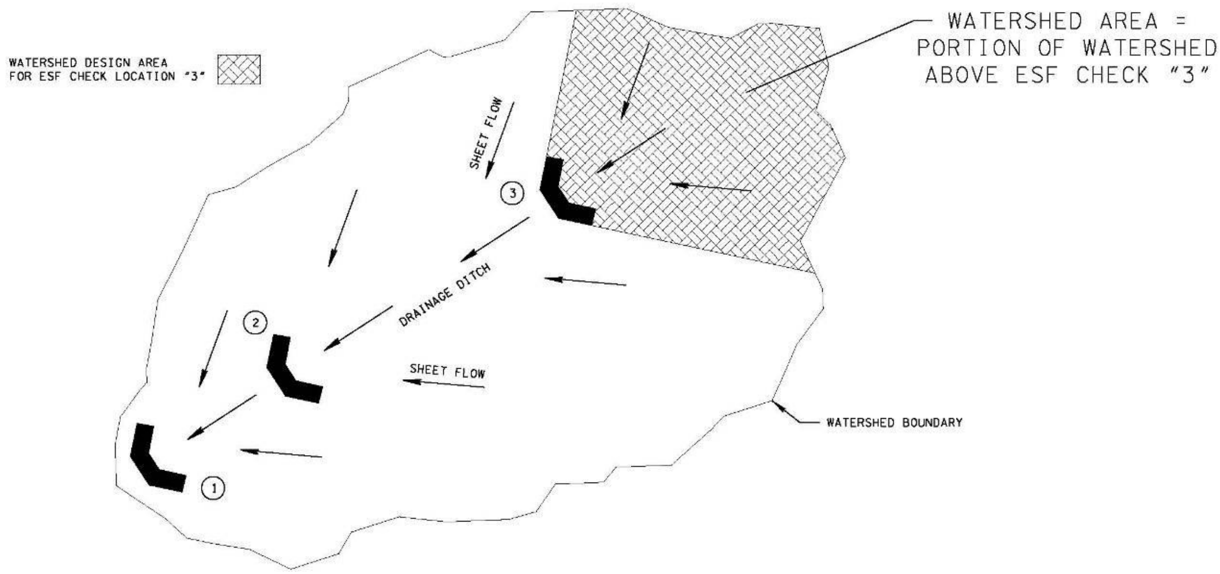


Figure 10EP-5
Location, Enhanced Silt Fence Check Number 3 (not to scale)

This area is analyzed using the Rational Method as described above. For a time of concentration of 6.7 minutes, rainfall intensities of 5.1 in/hr and 6.5 in/hr and flow rates of 13.5 cfs and 17.2 cfs are computed for the 2-year and 10-year storm events, respectively.

Based on site conditions, it is determined that the channel at this location should be 2.6 feet deep. Since 1 foot of freeboard is required, the allowable depth for the 10-year design flow will be 1.6 feet. As for the previous sites, Manning's Equation is used with an n-value of 0.07 to determine that a channel bottom width of 1 foot will provide sufficient conveyance to pass the ditch design flow at the required depth. However, the preliminary channel design will be based on the minimum bottom width of 4 feet. Once the enhanced silt fence check size has been determined, this bottom width may need to be further adjusted.

The "Limits of Flow" table on Standard Drawing EC-STR-4 indicates that a length of 4.2 feet of enhanced silt fence on the channel bottom would be required to pass the 2-year flow rate of 13.5 cfs. However, this also corresponds to a channel bottom width of 3 feet. Although it would be possible to adjust the channel bottom width to 3 feet upstream of this ESF check, it is decided to maintain the minimum bottom width of 4 feet. Thus, in order to provide an adequate length of enhanced silt fence at this location, the dimension "2L" will be increased to 5.7 feet, as prescribed on the "Limits of Flow" table (thus, "L" = 2.9 feet). Thus, the length of one side of the ESF check may be computed as:

$$L + X_1 + 6.0 = 2.9 + 8.5 + 6 = 17.4 \text{ feet}$$

This result is rounded to 18 feet, for a total ESF check length of 36 feet. It should be noted that the channel bottom does not need to be widened at this location.

Step 6: Design the overflow weirs: As described in the Planning and Design Criteria, each ESF check location should be provided with an overflow weir to pass flows when either the flow in the ditch exceeds the 2-year flow rate or the enhanced silt fence check becomes clogged with sediment. Since the design storm for the ditch is the 10-year event, the overflow weir should be designed to pass the peak discharge generated by that event with either 12 inches of freeboard on the fence or without overtopping the ditch banks, whichever is lower. Flows on the overflow can be analyzed with the sharp-crested weir formula (see Section 8.05 for additional information) which is as follows:

$$Q = \left(3.27 + 0.4\frac{H}{H_c}\right)(L - 0.2H)H^{1.5}$$

Where: Q = discharge over the overflow weir, (ft^3/s)
H = head above weir crest excluding velocity head, (ft)
H_C = height of the weir crest above the channel bottom, (ft)
L = horizontal weir length, (ft)

At the critical point, which is the most downstream ESF check location, the peak discharge in the 10-year event was found to be 44.8 cfs, and the channel was found to be 36 inches deep. In order to provide 12 inches of freeboard on the enhanced silt fence check, the upstream depth should be limited to 28 inches, which is less than the depth of the channel. Thus, freeboard on the ESF check is the limiting factor on the allowable upstream depth. Since the weir will be 18 inches above the channel bottom (i.e. – H_c = 1.5 feet), the maximum allowable depth on the weir, H, will be 10 inches, or 0.83 feet. Thus, the sharp-crested weir equation can be re-arranged and solved as:

$$L = \frac{Q}{\left(3.27 + 0.4\left[H/H_c\right]\right)\left(H^{1.5}\right)} + 0.2H = \frac{44.8}{\left(3.27 + 0.4\left[0.83/1.5\right]\right)\left(0.83^{1.5}\right)} + 0.2(0.83) = 17.1 \text{ feet}$$

Because the fence posts are to be spaced at 2-foot intervals, it is necessary to round the required weir length up to 18 feet. In the design of this ESF check, it was noted that the total length of the fence within the channel bottom (dimension "2L" on the standard drawing) will be 21.2 feet; thus, the entire weir length can be accommodated within the channel bottom width. Since the standard drawing also shows that a post will be placed on the center line of the channel, the weir length will be arranged such that 10 feet of the overflow weir will be on one side of the center line and the remaining 8 feet will be on the other side.

At the second ESF check, the 10-year peak discharge was found to be 32.2 cfs and the channel was found to be 2.7 feet, or 32 inches deep. Thus, following the logic described for the first ESF check, the maximum depth on the weir, H, will be 0.83 feet. The required weir length is computed as:

$$L = \frac{Q}{\left(3.27 + 0.4\left[H/H_c\right]\right)\left(H^{1.5}\right)} + 0.2H = \frac{32.2}{\left(3.27 + 0.4\left[0.83/1.5\right]\right)\left(0.83^{1.5}\right)} + 0.2(0.83) = 12.4 \text{ feet}$$

Because this result is only slightly greater than the nearest 2-foot increment of length, the weir length is rounded down to 12.0 feet. In the design of this ESF check, the dimension "2L" was found to be 12.7 feet, and L was found to be 6.4 feet. Thus, the overflow weir can be accommodated within the channel bottom width, arranged so that 6 feet of weir length will be on either side of the center line fence post.

At the third ESF check, the 10-year peak discharge was found to be 17.2 cfs and the channel was found to be 2.6 feet, or 31 inches deep. Thus, the maximum depth on the weir, H, will still be 0.83 feet. The required weir length is computed as:

$$L = \frac{Q}{\left(3.27 + 0.4\left[H/H_c\right]\right)\left(H^{1.5}\right)} + 0.2H = \frac{17.2}{\left(3.27 + 0.4\left[0.83/1.5\right]\right)\left(0.83^{1.5}\right)} + 0.2(0.83) = 6.7 \text{ feet}$$

Because this result is not sufficiently close to 6.0 feet to allow the weir length to be rounded down, it is rounded up to 8 feet. However, the dimension "2L" for this site was found to be 5.7 feet, which means that the weir length cannot be accommodated within the channel bottom. With the overflow weir arranged so that 4 feet of length will be provided on either side of the center line fence post, the weir will overlap the sides of the channel by a distance of about 1.2 feet on either side. This will not present an additional erosion problem since the sides of the channel will be lined with machined riprap Class A-1. Further, it is assumed that the contractor will install the fence prior to cutting the material to form the weir. Thus, it will be possible to maintain a level weir height on the inclined sides of the channel.

Step 7: Determine quantities for enhanced silt fence checks: The pay items for the proposed enhanced silt fence checks include:

<u>Item number 209-08.06: Enhanced Silt Fence Check (Trapezoidal), per Each</u>

The final quantity for this item will be 3.

<u>Item number 209-05: Sediment Removal, per CY</u>

For additional details on computing Item 209-05, Sediment Removal, refer to Section 10.04.6.2.

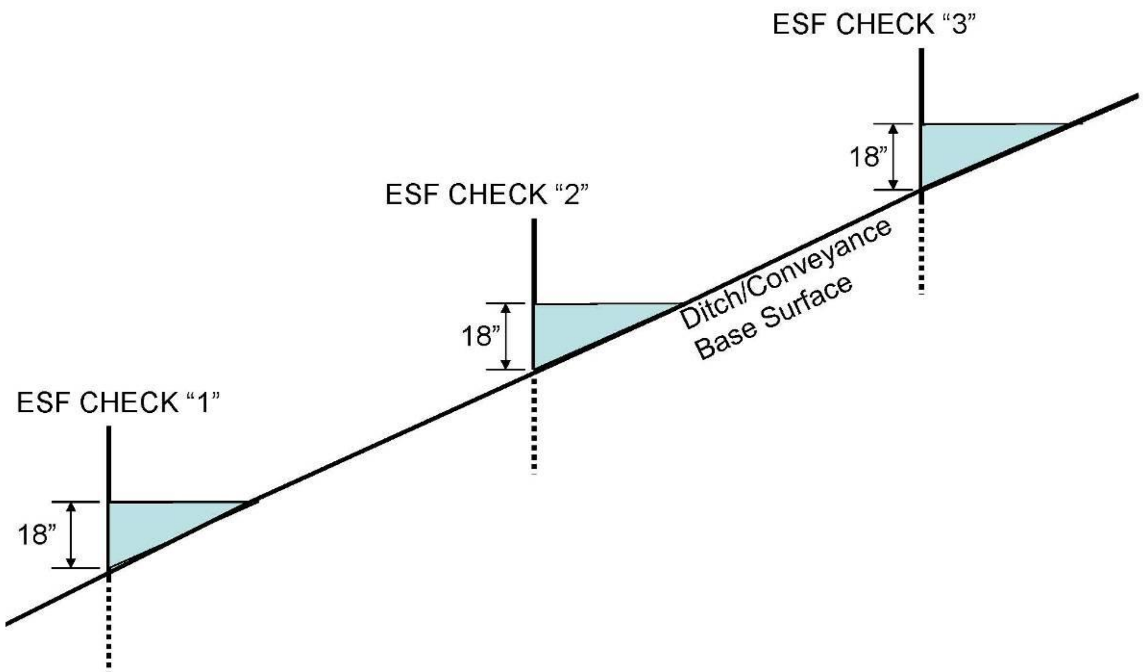
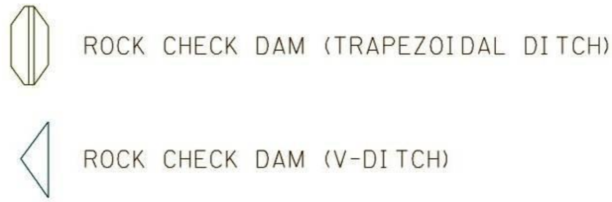


Figure 10EP-6
Typical Stream Profile with Enhanced Silt Fence Checks

10.08.1.2 ROCK CHECK DAM (EC-STR-6)

Installation of Rock Check Dams
Location: SR-37, Carter County, TN (2004)



10.08.1.2.1 DEFINITION AND PURPOSE

This erosion prevention measure consists of a small temporary riprap dam constructed across a swale, drainage ditch or other area of concentrated flow. Rock check dams are intended to prevent erosion by reducing the velocity of stormwater flow in a waterway. While small amounts of sediment will be collected by a check dam, it should not be considered a sediment trapping device.

10.08.1.2.2 APPROPRIATE APPLICATIONS

This BMP is applicable for use in small open channels which drain 10 acres or less. Specific applications include:

- temporary or permanent swales or ditches in need of protection during establishment of grass linings
- temporary or permanent swales or ditches which, due to a short length of service or for other reasons, cannot receive a permanent non-erodible lining for an extended period of time
- other locations where small localized erosion and resulting sedimentation problems exist

10.08.1.2.3 LIMITATIONS

The main function of a rock check dam is to decrease velocity and prevent erosion, not to collect sediment. Sediment control may be provided by using an Enhanced Rock Check Dam (EC-STR-6A) as described in Section 10.08.2.6. Rock check dams should not to be used in a stream with perennial flows.

Rock check dams should not be used in streams or wetlands. The use of this measure in waterways may require an Aquatic Resources Alteration Permit (ARAP) from the Tennessee Department of Environment and Conservation and possibly a Section 404 permit from the U.S. Army Corps of Engineers.

10.08.1.2.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is not required. However, rock check dams should be shown in the EPSC plans based on EC-STR-6, supplemented with the following criteria.

The drainage area at any given check dam should not be more than 10 acres.

The height of the dam at the center should be at least 1 foot lower than its height at the outer edges. This will form a weir to minimize the potential for erosion due to flows around the ends of the dam where the rock check dam and natural ground meet.

The height of the weir at the center of the dam should be a minimum of 1 foot above the ditch bottom (2 feet minimum for sites that drain to Exceptional Tennessee Waters or sediment-impaired streams). The weir may be as high as 3 feet above the channel bottom, provided that the overall structure would not be higher than the ditch banks. The upstream and downstream faces of the dam should be at a slope of 3H:1V.

Rock check dams should be constructed from machined riprap Class A-1. Mechanical placement may be required to insure that the dam covers the entire width of the waterway and that the center of dam is lower than its edges.

The maximum spacing between dams should be such that the toe of the upstream dam is at the same elevation as the crest of the weir on the downstream dam. Standard Drawing EC-STR-6 provides a chart which may be used to determine spacing based on this criterion.

Geotextile fabric (Type III) should be placed under the base of the check dam and should extend 3 feet beyond the downstream limits of the machined riprap. This fabric should meet the requirements of the standard specification for geotextiles, AASHTO designation M-288, Erosion Control.

Rock check dams shall be paid for under the following item numbers:

- 209-05, Sediment Removal, per CY
- 209-08.07, Rock Check Dam, per Each

10.08.1.2.5 EXAMPLE APPLICATION

Given: A proposed V-ditch with 6H:1V side slopes has been designed along a roadway. The proposed ditch will be 200 feet long, and have a grade of 2% and a depth of 3.5 feet.

Find: Determine the required check dam size and spacing and calculate the required quantities.

Solution:

Step1: Determine the height of the structure: Since the ditch is 3.5 feet deep, and the height at the center of the structure is to be 1 foot less than at the sides of the ditch, the height of the structure at the center will be 2.5 feet.

Step2: Determine the number of rock check dams required: Based on the figure provided on Standard Drawing EC-STR-6, the rock check dams should be spaced every 125 feet.

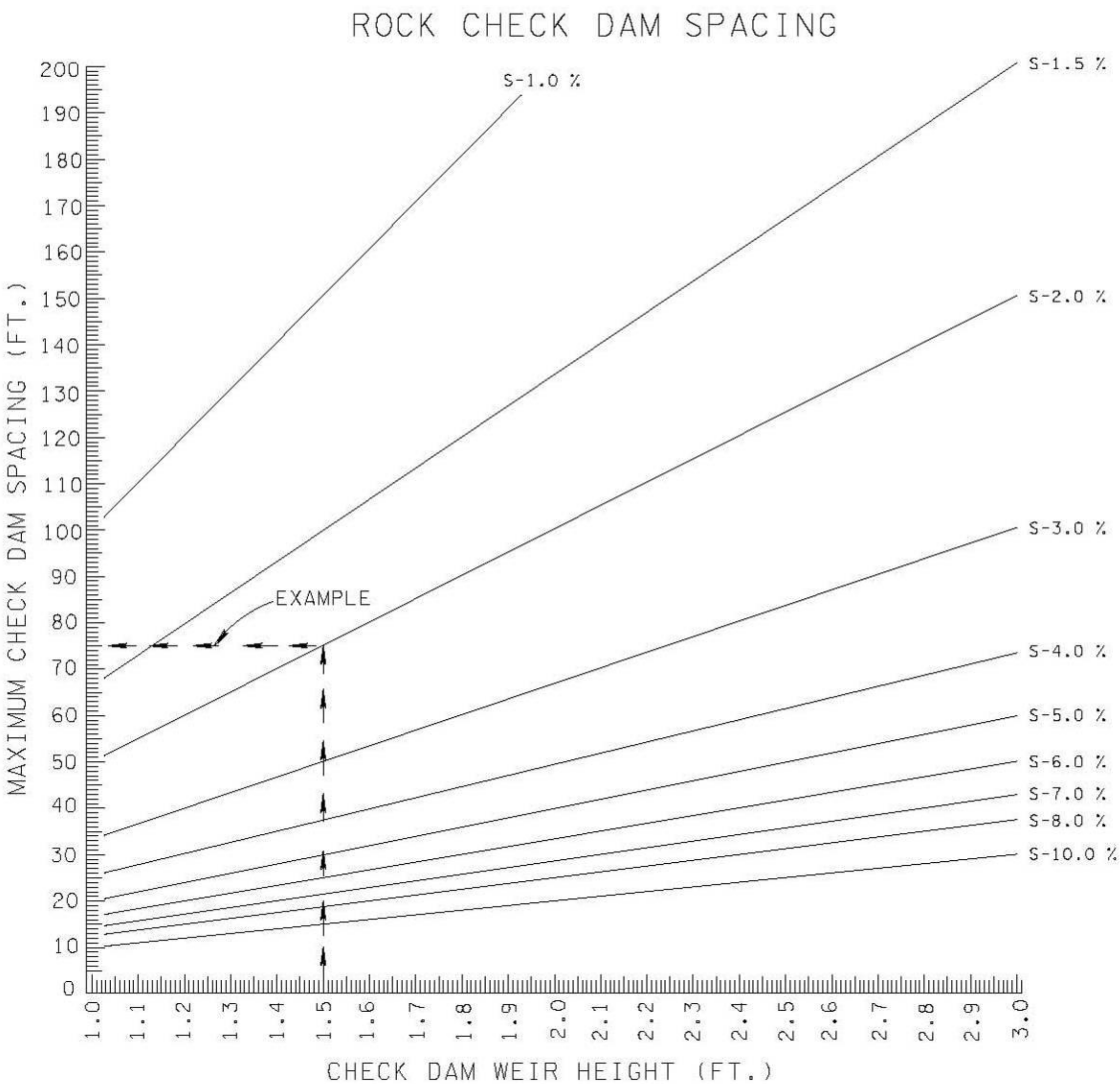


Figure 10EP-7
Rock Check Dam Spacing

Thus, the number of check dams needed may be computed by dividing the length of the ditch by the required spacing:

$$\frac{200}{125} = 1.60 \approx 2$$ Check dams

Step3: Determine quantities: The pay items for these check dams are:

Item Number 209-05, Sediment Removal, per CY

For additional details on computing Item 209-05, Sediment Removal, refer to Section 10.04.6.2.

Item Number 209-08.07, Rock Check Dam, per Each

The final quantity for this item is 2.

10.08.1.3 TEMPORARY CONSTRUCTION EXIT (EC-STR-25)

Temporary Construction Exit
Location: SR-448, Sevier County, TN (2005)

10.08.1.3.1 DEFINITION AND PURPOSE

A temporary construction exit consists of a stone pad on geotextile fabric located at any point where traffic will be moving from a construction site onto a public roadway or other paved area.

This erosion prevention device provides a buffer area where mud and caked soil can be removed from the tires of construction vehicles to avoid transporting it onto public roadways or other paved areas. The stone pad should be constructed so that vehicle tires will sink in slightly as they pass over the stone. This erosion prevention measure is effective in reducing the tracking of mud and dirt from a project site.

10.08.1.3.2 APPROPRIATE APPLICATIONS

This practice should be applied at construction site exits where project equipment, trucks, etc. will access a public road.

Temporary construction exits are required on all projects with one acre or more of disturbed area. On some projects (i.e. widening projects) the location for a temporary construction exit may not be apparent to the designer during project development. In these cases, the designer shall include quantities for at least two (2) temporary construction exits in the estimate and note on the EPSC plans “Temporary construction exit to be located by the Engineer”.

10.08.1.3.3 LIMITATIONS

None.

10.08.1.3.4 PLANNING AND DESIGN CRITERIA

While formal design not required, the following standards should be used:

A layer of geotextile fabric (Type III) is required to stabilize and support the pad aggregate. This geotextile fabric should extend the full length and width of the construction exit. This fabric should meet the requirements of the standard specification for geotextiles, AASHTO designation M-288, Erosion Control.

The stone pad should be constructed of Machined Riprap, Class A-3, with a minimum thickness of 12 inches. At minimum, the stone pad should be 50 feet long and 12 feet wide. A minimum turning radius of 20 feet should be provided on each side of the pad where it intersects with the public roadway.

The entire area of the temporary construction exit should be excavated to a minimum depth of 3 inches and be cleared of all vegetation, roots and other objectionable materials.

Top-dressing the stone pad with additional stone may be required should it become clogged with excessive amounts of trapped sediments during the life of the measure. Any soil tracked onto the public roadway should be removed immediately.

If the pad slopes towards the public road at a grade exceeding 2%, a mountable berm (water bar diversion) at least 6 inches high with 3H:1V side slopes should be provided at the end of the pad to prevent sediment laden runoff from entering the public roadway. Provisions should be made to direct this sediment laden runoff into a suitable sediment trapping device.

At the discretion of the construction engineer, a temporary drainage pipe may be provided where it is anticipated that the stabilized pad will impede ditch or adjacent flow.

Temporary construction exits shall be paid for under the following item numbers:

- 203-01, Road and Drainage Excavation (Unclassified), per CY
- 709-05.05, Machined Rip-Rap (Class A-3), per Ton
- 740-10.03, Geotextile (Type III) (Erosion Control), per SY

10.08.1.3.5 EXAMPLE APPLICATION

Given: Calculate the quantities for a single Temporary Construction Exit.

Solution: The pay items for this measure include:

<u>Item Number 740-10.03, Geotextile (Type III) (Erosion Control), per SY</u>

The surface area of a 12-foot by 50-foot pad is 600 sf. Add 86 square feet for each of the 20-foot turning radii at the public roadway for a total area of 772 square feet. Convert this to 85.8 SY to determine the quantity of geotextile required.

<u>Item Number 709-05.05, Machined Rip-Rap (Class A-3), per Ton</u>

Since the stone pad is to be 12 inches thick, 772 cubic feet of stone will be required, which corresponds to 28.6 CY. Based on 1.75 tons per CY and as specified in Section 10.04.6.1, the total weight of riprap required will be 50.0 tons.

Item Number 203-01, Road and Drainage Excavation (Unclassified), per CY

The depth of excavation will be 3 inches, which is 0.25 feet. Multiplying by 772 s.f. yields 193 cubic feet, which corresponds to 7.15 CY of excavation required.

10.08.1.4 TEMPORARY CULVERT CROSSING (EC-STR-25)

Temporary Culvert Crossing
Location: Hardeman County, TN (2004)

10.08.1.4.1 DEFINITION AND PURPOSE

This measure consists of a temporary structure installed across a flowing watercourse for use by construction equipment.

10.08.1.4.2 APPROPRIATE APPLICATIONS

Temporary culvert crossings are used to provide the contractor with a means to cross a ditch or stream during construction without causing damage to the channel or banks and to keep sediment generated by construction traffic out of the waterway.

10.08.1.4.3 LIMITATIONS

This BMP should be in place for less than a year and should not be accessible to the general public.

The installation of a temporary culvert crossing will require an Aquatic Resources Alteration Permit (ARAP) from the Tennessee Department of Environment and Conservation. A Section 404 permit from the Corps of Engineers may also be required. This should be considered during the planning stages of the EPSC plans. Additionally, the temporary culvert(s) may not be permitted in streams with sensitive or endangered aquatic life.

10.08.1.4.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is required in that the hydrologic and hydraulic analysis of the waterway is necessary in order to determine the number and size of pipes required for a temporary culvert crossing. For each temporary culvert crossing the number, diameter, and length of temporary drainage pipes and the type of driving surface should be labeled in the EPSC Plans.

The selection of the number and size of pipes to be used in the crossing should be based on the table “Temporary Diversion Culvert Selection” on Standard Drawing EC-STR-32. Where the size for a single pipe determined from the table will not adequately fit into the channel, Table 10A-13 in the Appendix may serve as an aid in selecting multiple pipes.

This measure may include one or more temporary pipes (culverts) from 18 inches to 72 inches in diameter. The culverts should be covered with machined riprap Class A-1, and the driving surface should consist of a minimum of 6 inches of mineral aggregate, (size 57).

When this measure is applied at sites which drain to Exceptional Tennessee Waters or sediment-impaired streams, the Mineral Aggregate (Size 57) used to form the driving surface should be changed to a minimum 9-inch layer of Machined Riprap, Class A-3.

Geotextile fabric (Type III) should be placed on the streambed and stream banks prior to the placement of the temporary drainage pipe and aggregate. Geotextile fabric (Type III) should also be placed under the entire width of machined riprap, Class A-3. This fabric should meet the requirements of the standard specification for geotextiles, AASHTO designation M-288, Erosion Control.

When possible, construction of the temporary culvert crossing should be performed during no or low flow conditions. Where low flows are present, a coffer dam may be used upstream to allow the placement of the temporary culvert to be done in the dry. Clearing of the stream bed and banks should be kept to a minimum.

The crossing should be perpendicular to the stream. Where this is not practical, the crossing should be skewed no more than 15 degrees.

Provision should be made to prevent construction road runoff from entering the stream. The preferred method for accomplishing this is to provide low approaches which will form “sag” points on either side of the stream channel. Runoff into these “sag” points should be directed into erosion-resistant areas adjacent to the access road. These low approaches will also facilitate the safe passage of flood flows greater than the design flow rate. However, these “sag” points should be no lower than the crown of the temporary culvert, if possible. Where “sag” points cannot be constructed, low berms, 6 inches high with 5H:1V side slopes may be placed on either side of the channel to divert flows.

Provision should also be made to ensure that runoff from the construction site does not enter the stream at the point of the crossing. Unstable stream banks should be lined with riprap or otherwise appropriately stabilized. Any debris which collects on the temporary culverts should be immediately removed.

Temporary culvert crossings shall be paid for under the following item numbers:

- 203-01, Road and Drainage Excavation (Unclassified), per CY
- 303-10.01, Mineral Aggregate (Size 57), per Ton
- 621-03.02 thru 621-03.11, 18” to 72” Temporary Drainage Pipe, per LF
- 709-05.05, Machined Rip-Rap (Class A-3), per Ton
- 709-05.06, Machined Rip-Rap (Class A-1), per Ton
- 740-10.03, Geotextile (Type III) (Erosion Control), per SY

10.08.1.4.5 EXAMPLE APPLICATION

Given: A temporary culvert crossing is to be constructed across a stream which has the following characteristics:

- Drainage Area = 120 acres (0.1875 square miles)
- Hydrologic Area 2
- Slope of stream at site = 1.0%
- Channel bottom width = 8 feet
- The channel side slopes are 3.5 feet high at a slope of 1.5H:1V
- Runoff Curve Number CN=75, Wilson County
- Time of Concentration, T_c =1 hour
- Rainfall Distribution Type II
- Assume no pond and swamp areas

Find: Design the temporary culvert crossing for this site and compute the required quantities.

Solution:

Step 1: Determine the design flow rate: The design flow rate should be based on the 2-Year, 24-hour storm. Since the drainage area at this site is greater than 100 acres, the TR-55 Graphical Peak Discharge Method will be used. The design flow rate is computed as follows:

- For a 2-Year, 24 Hour storm the Rainfall, P = 3.64” (Table 4A-5)
- Initial abstraction, I_a = 0.667” (Table 4-1, Technical Release 55)
- Compute I_a/P

$$\frac{I_a}{P} = \frac{0.667}{3.64} = 0.183$$

- Unit Peak Discharge, q_u = 340 csm/in (Exhibit 4-II, Technical Release 55)
- Runoff, Q

$$S = \frac{1000}{CN} - 10 = \frac{1000}{75} - 10 = 3.333 \text{ (Equation 2-4, Technical Release 55)}$$

$$Q = \frac{(P-0.2S)^2}{(P+0.8S)} = \frac{(3.64-0.2(3.33))^2}{(3.64+0.8(3.33))} = 1.401'' \text{ (Equation 2-3, TR 55)}$$

- Pond and Swamp Adjustment Factor, F_p = 1.0 (Table 4-2, Technical Release 55)
- Peak discharge, q_p

$$q_p = q_u A_m Q F_p = (340)(0.1875)(1.401)(1.0) = 89.3 \text{ cfs (Equation 4-1, TR 55)}$$

Step 2: Select pipe size and number: The table “Temporary Diversion Culvert Selection” on Standard Drawing EC-STR-32 indicates that a single 48-inch pipe would offer a capacity of 88 cfs for a slope of 1.0%, which is less than design flow rate but will be sufficient. However, as indicated on EC-STR-25, this pipe would require 2 feet of cover in addition to 6 inches of mineral aggregate (size 57). Thus, the total height of this structure would be 6.5 feet, which is judged to be too large to fit into the channel height. As an alternative, twin 36-inch pipes are considered. These pipes would offer a combined capacity of 100 cfs, which is more than adequate. Based on EC-STR-25, the spacing between the pipes should be 1.5 feet for a total width of 7.5 feet, which can be accommodated in the channel bottom. Further, these pipes require 1.5 feet of cover, which combined with 6 inches of mineral aggregate (size 57), results in a total height of 5.0 feet. This height is judged to be a much better fit compared to the channel height, and twin 36-inch pipes are selected for the crossing.

Step 3: Compute Quantities: The quantities for this crossing include:

<u>Item Number 303-10.01, Mineral Aggregate (Size 57), per Ton</u>

In order to compute the quantity of mineral aggregate (size 57), it is first necessary to compute the plan dimensions of the "footprint" of the material. As shown in Figure 10EP-8, the width of this material will be 12 feet. Since it is to be extended 50 feet on either side of the channel banks, it is first necessary to compute the top width of the channel. From the channel dimensions provided above, it is possible to compute the channel top width as:

$$W = bottom\,width + 2(Side\,Slope)(Channel\,Height) = 8 + 2(1.5)(3.5) = 18.5 \text{ feet}$$

Adding the 50-feet of additional length on either side of the channel yields a total length of approximately 119 feet. Thus, the volume of aggregate required may be computed as:

$$Volume = (119)(12)(0.5) = 714\,CF / 27 = 26.4 \text{ CY}$$

Multiplying this by 1.75 Tons/CY yields a final quantity of 46.2 tons.

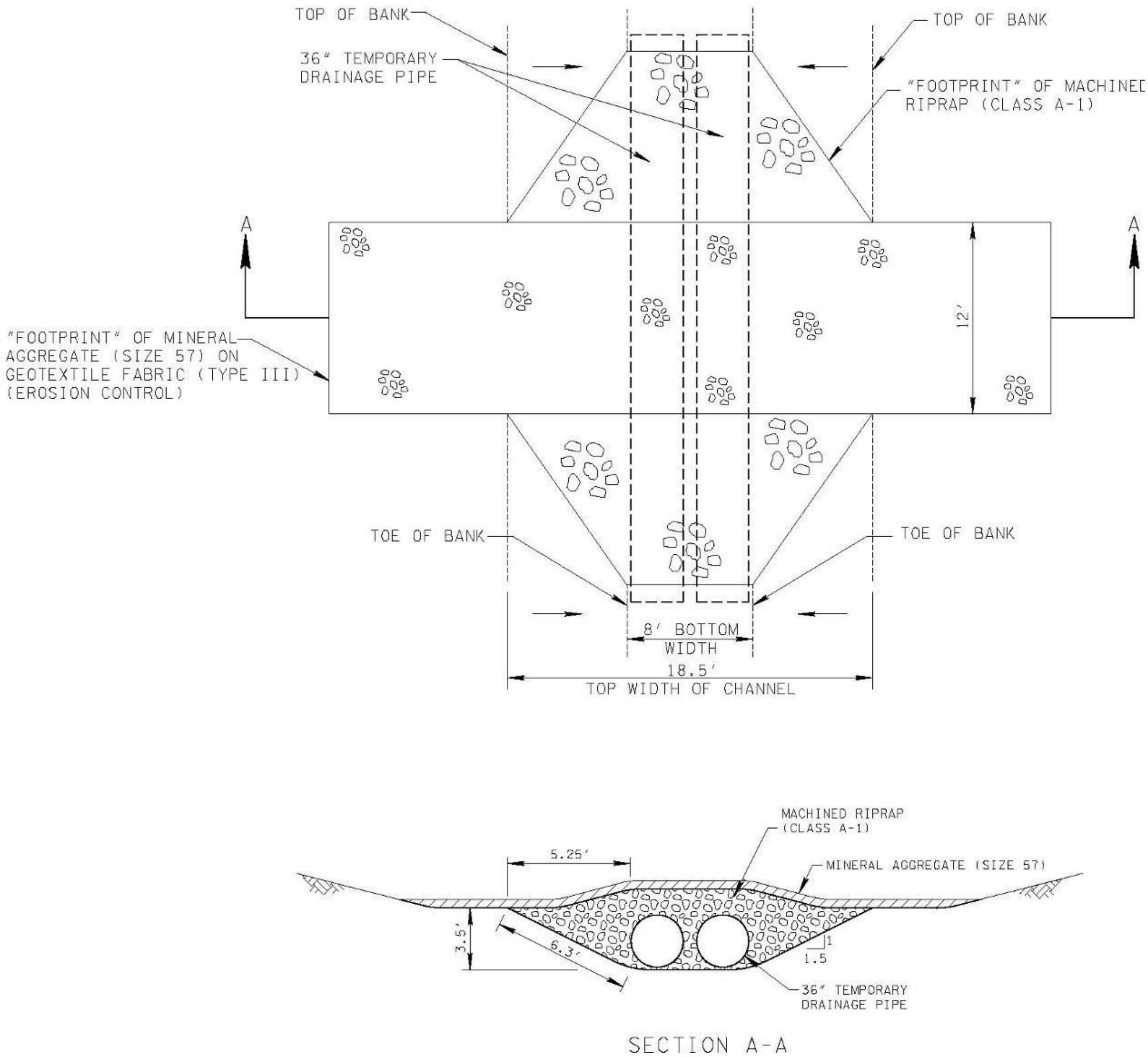


Figure 10EP-8
Plan and Profile of Temporary Culvert Crossing Installation

Item Number 621-03.05, 36-inch Temporary Drainage Pipe, per LF

Before computing the required quantity of 36-inch temporary drainage pipe, it is necessary to determine the dimension of the riprap fill along the stream bottom. The height of the fill was determined to be 5.0 feet and the top width is 12 feet. In addition, it is assumed that the sides of the fill will be at a 2H:1V slope. Thus, the length along the stream may be computed as:

$$L = 12 + 2(2)(5) = 32 \text{ feet}$$

Since the pipes will extend 1 foot from the toe of the fill on both sides, the length of each pipe will be 34 feet, for a total quantity of 68 LF.

Item Number 709-05.06, Machined Rip-Rap (Class A-1), per Ton

Computing the required quantity of machined riprap Class A-1 will require that the plan area and average height of the riprap fill be determined. It was determined above that the length of the fill along the channel bottom will be 32 feet, and the width of the channel bottom was given as 8 feet. In addition, the length of the fill will transition from 32 feet at the channel bottom to 12 feet at the top of bank on both sides of the channel. Thus, the plan area of the fill may be computed as:

$$Plan\ Area = (8)(32) + 2(5.25)\left(\frac{32+12}{2}\right) = 487 \text{ SF}$$

The average height of the fill may be computed as a weighted average of the fill height across the width of the channel. It should be noted that, since the quantity of the mineral aggregate (size 57) is not included, the maximum height of the machined riprap Class A-1 is 4.5 feet. Thus, the weighted average height may be computed as:

$$Average\,Height = \frac{(8)(4.5) + 2(5.25)\left(\frac{4.5+3.5}{2}\right)}{18.5} = 4.2 \text{ feet}$$

Thus, the total volume within the riprap fill may be computed as:

$$Total\,Volume = (Plan\ Area)(Average\,Height) = (487)(4.2) = 2045.4 \text{ CF}$$

The volume above includes volume which will be occupied by the proposed temporary drainage pipes and it is thus necessary to subtract out that volume to determine the final quantity. The average length of the pipes inside the fill (as opposed to the total length of the pipes) will be 29 feet. Thus, the volume occupied by these pipes may be computed as the length times the end area:

$$Pipe\,Volume = 2(29)(29)\left[\pi\left(1.5^2\right)\right] = 410.0 \text{ CF}$$

Subtracting the pipe volume yields a net volume of 1635.4 CF, or 60.6 CY. Multiplying by 1.75 tons per CY produces the final quantity of 106.0 tons.

Item Number 740-10.03, Geotextile (Type III) (Erosion Control), per SY

Since geotextile fabric is to be placed under both the machined riprap Class A-1 and the mineral aggregate (size 57), it will be necessary to compute the quantity for this material in two parts. First, the plan area of the mineral aggregate (size 57) was determined above to be 119 feet by 12 feet, or 1428 SF, which corresponds to an area of 159 SY.

The second part of this quantity is the area of the material to be placed beneath the machined riprap Class A-1. In computing the quantity of riprap required, it was sufficient to compute the plan area of the "footprint" of that material. However, the geotextile is to be placed on the sloping sides of the channel, and it is necessary to account for that slope. Figure 10EP-8 shows that the length of the sloping side of the channel is 6.3 feet. Thus, the area of geotextile require may be computed as:

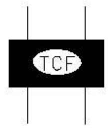
$$Area = (8)(32) + 2(6.3)\left(\frac{32+12}{2}\right) = 533.2\,SF/9 = 59.2 \text{ SY}$$

Thus, the total quantity of geotextile required is:

$$Area = 159.0 + 59.2 = 218.2 \text{ SY}$$

Multiple Pipes at Temporary Culvert Crossing
Location: SR-224, McNairy County, TN (2005)

10.08.1.5 TEMPORARY CONSTRUCTION FORD (EC-STR-25)



TEMPORARY CONSTRUCTION FORD

Temporary Construction Ford
Reference: NCDOT (2003)

10.08.1.5.1 DEFINITION AND PURPOSE

This erosion prevention measure consists of a layer of stone on geotextile fabric installed on the bottom of a ditch or swale. It provides short term access across the ditch or swale for construction vehicles and heavy equipment.

This measure is used to provide the contractor with a temporary means to cross a side ditch or shallow swale without damaging the channel or depositing sediment where it could be picked up by intermittent flows.

10.08.1.5.2 APPROPRIATE APPLICATIONS

A temporary construction ford should be used at locations where wide, shallow depressions or side ditches must be crossed on a short term basis during the course of construction. Temporary construction fords may be installed where:

- alternate access routes impose significant constraints
- construction activities will last no more than a year
- channel banks are no more than 5 feet high

Temporary construction fords are best-suited to roadside ditches or intermittent swales.

10.08.1.5.3 LIMITATIONS

Temporary construction fords should be designed and constructed to minimize the blockage of flow and to allow free flow over the ford. The placement of material in the watercourse may cause some upstream ponding. The depth of this ponding will be equivalent to the depth of the material placed within the stream and should be limited to 12 inches or one-half the height of the existing banks, whichever is smaller.

Temporary construction fords shall not be used in streams, wetlands, or other natural water resources.

10.08.1.5.4 PLANNING AND DESIGN CRITERIA

When possible, construction of the temporary construction ford should be performed when flow is not anticipated in the watercourse. The temporary crossing should be constructed perpendicular to the watercourse. Where this is not feasible, the skew of the crossing, normal to flow, should be no more than 15 degrees. If possible, select a location for the crossing where it will disturb the least amount of the channel banks and bottom.

The approaches to the ford should be excavated into the channel banks so that the approach slopes are no steeper than 5H:1V. This excavation should be accomplished by pulling material back from the channel, not by pushing soil into the watercourse. The width of the temporary ford, as well as the approaches to the crossing, should be between 12 and 20 feet. Provision should be made to prevent surface runoff from the construction road above the ford from entering the watercourse. This may accomplished by placing low berms or diversions, 6 inches high with 5H:1V side slopes, on either side of the channel to divert runoff from the construction ford before it enters.

The stone layer of the ford should consist of machined riprap Class A-3, and be limited to 12 inches thick. It should be placed on geotextile fabric (Type III) across the channel bottom and banks. The fabric should meet the requirements of the standard specification for geotextiles, AASHTO designation M-288, Erosion Control.

When the temporary construction ford is no longer needed, all stone and geotextile fabric should be removed and the channel banks should be restored as closely as practical to their original dimensions. Soil left exposed should be stabilized by seeding with mulch or seeding with erosion control blanket, as appropriate.

Temporary construction fords shall be paid for under the following item numbers:

- 203-01, Road and Drainage Excavation (Unclassified), per CY
- 709-05.05, Machined Rip-Rap (Class A-3), per Ton
- 740-10.03, Geotextile (Type III) (Erosion Control), per SY

10.08.1.5.5 EXAMPLE APPLICATION

Given: A temporary construction ford is to be constructed across a roadway side ditch which has the following characteristics:

- Ditch bottom width = 4 feet
- The channel side slopes are 3.5 feet high at a slope of 3H:1V
- The ditch has a grassed lining

Find: Compute the required quantities for this crossing.

Solution: The quantities for this crossing include:

Item Number 203-01, Road and Drainage Excavation (Unclassified), per CY

Since the ditch has a grassed lining, the bottom will be excavated to a depth of 12 inches in order to provide a firm base for the stone layer and to ensure that it will not cause an obstruction to flow. Thus, the total height from the bottom of the excavation to the point where the excavated slope meets the existing grade will be 4.5 feet. Since the approaches will be excavated to a 5H:1V slope, the length of the excavation on one side will be:

$$L = (Height)(Side\,Slope) = (4.5)(5) = 22.5 \text{ feet (use 23 feet)}$$

The volume within the excavated area on one bank will be equal to the length of the excavation times the average cross sectional area of the excavation. Since the proposed ford will have a width of 12 feet, and the side slopes of the excavation will be 2H:1V, the cross sectional area adjacent to the channel may be computed as a trapezoid:

$$\begin{aligned} Area\,at\,channel &= (Base)(Height) + (Side\,Slope)(Height^2) \\ &= (12)(4.5) + (2)(4.5^2) = 94.5 \text{ SF} \end{aligned}$$

Since the cross sectional area is zero where the excavated slope meets the existing grade, the average cross sectional area may be computed as half of the area adjacent to the channel, or 47.3 SF. Thus, the total volume of excavation for one side of the channel is:

$$Volume = (23)(47.3) = 1087.9 \text{ CF}$$

However, a large portion of this volume is “empty air” above the exiting ditch side slope. As stated above, the height of the channel is 3.5 feet. Thus, the length along the 3H:1V slope is:

$$L = (Channel\ \ Height)(Side\,Slope) = (3.5)(3) = 10.5 \text{ feet}$$

Using similar logic as was employed above, the volume of “empty air” above the channel side slope may be computed as:

$$"Empty\ Air" = \frac{1}{2}\left[(12)(3.5) + (2)(3.5^2)\right] \times 10.5 = 349.1 \text{ CF}$$

The net volume to be excavated on one side of the channel may then be computed as:

$$Volume_{Side} = 1087.9 - 349.1 = 738.8 \text{ CF}$$

The volume to be excavated on the ditch bottom may be computed as:

$$Volume_{Bottom} = (1)(12)(4) = 48 \text{ CF}$$

The total volume to be excavated is thus:

$$Volume_{Total} = 48 + (2)(738.8) = 1525.6 \text{ CF}$$

Dividing this result by 27 yields the final quantity of 56.5 CY.

Item Number 709-05.05, Machined Rip-Rap (Class A-3), per Ton

As noted above, the length of excavation on each side of the channel will be 23 feet. The total length of the ford will thus be:

$$L = 2(23) + 4 = 50 \text{ feet}$$

Since the width of the ford will be 12 feet, the area covered by the riprap will be:

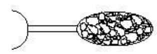
$$Area = (12)(50) = 600 \text{ SF}$$

Since the depth of the riprap will be 1 foot, the volume will be 600 CF, which is equal to 22.2 CY. Multiplying by 1.75 tons per CY, as specified in Section 10.04.6.1, yields a final quantity of 38.9 tons.

Item Number 740-10.03, Geotextile (Type III) (Erosion Control), per SY

As noted above, the area of the riprap layer will be 600 SF. Since the area required for the geotextile will be equal to that area, the final quantity for geotextile will be 600 SF or 66.7 SY.

10.08.1.6 TEMPORARY SLOPE DRAIN (EC-STR-27)



Temporary Slope Drain
Reference: Handbook for Sediment and Erosion Control, Ohio DOT (2000)

10.08.1.6.1 DEFINITION AND PURPOSE

This erosion prevention measure consists of a temporary, flexible conduit or tubing used to convey concentrated stormwater from the top of a cut or fill slope to its base.

Temporary slope drains convey concentrated stormwater runoff from the area above a steep cut or fill slope to an appropriate outlet at the toe, thus protecting the slope from erosion.

10.08.1.6.2 APPROPRIATE APPLICATIONS

Temporary slope drains are used on cut and fill slopes where concentrated stormwater runoff from above the slope could cause erosion damage. Slope drains may be used while an embankment is being constructed and after final grade is achieved on the slope.

Cut and fill slopes are particularly vulnerable to erosion during the period of time between the completion of the cut or fill slopes and the installation of a permanent drainage system and slope stabilization measures. This period can be a significant length of time and temporary slope drains, if correctly installed, can provide protection to the exposed slope.

Temporary slope drains are normally used in conjunction with temporary berms, which are placed at the top of the slope to direct runoff into the entrance of the temporary pipe.

Slope drains are an effective erosion prevention device on long and/or steep slopes where stabilization requirements are more stringent. They should also be considered for use on the low side of super-elevated sections of roadway where additional concentrated flow exits, especially in small radius horizontal curves.

10.08.1.6.3 LIMITATIONS

The maximum drainage area for any single temporary slope drain shall be 1.5 acres.

10.08.1.6.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is not required. However, for each temporary slope drain the diameter should be labeled in the EPSC Plans. When temporary slope drains are utilized, the following standards should be used.

Temporary slope drains should be placed on undisturbed soil or well-compacted fill.

The diameter of the slope drain should provide sufficient capacity to convey the maximum runoff expected during the life of the drain. The pipe diameter should be selected according to the table “Temporary Slope Drain Sizes” shown on Standard Drawing EC-STR-27.

The pipe should be constructed using corrugated metal or more normally HDPE pipe. The pipe sections should be securely fastened together and have watertight fittings. Use reinforced hold-down grommets or stakes to anchor the pipe at intervals not to exceed 10 feet. The outlet end of the pipe should be anchored with riprap as shown on Standard Drawing EC-STR-27.

The pipe should extend beyond the toe of the slope a minimum of 4 feet. This section of the pipe should be horizontal to help reduce the outlet velocity. As an alternative, a “tee” or an “ell” section may be placed at the outlet end of the pipe. These sections can serve to reduce velocity during high flow conditions, as well as to direct flows into a drainage ditch or other conveyance.

Where the inlet of the pipe is at a low point, the area around the inlet should be compacted and graded to channel flows toward the pipe inlet. Where the inlet of the pipe is on a continuous slope, flows should be diverted into the inlet by constructing an earth berm ditch block as shown on Standard Drawing EC-STR-27. The ditch block should be of sufficient height to block the flow of water, but must be lower than the berm constructed along the top of the slope.

The earthen berm across the top of the slope should be at least 6 inches above the top of the temporary slope drain pipe. Where this height is greater than necessary for the rest of the berm, a transition may be provided at a slope of 3H:1V. The top of the berm should have a minimum width of 2 feet and side slopes no steeper than 2H:1V.

Where economically justified, multiple pipes may be used in place of a single temporary slope drain to accommodate drainage areas larger than 1.5 acres. The sum of the maximum drainage areas for the multiple pipes should be greater than or equal to the area to be drained. For example, a drainage area of 2 acres could be served by an 18-inch pipe combined with a 15-inch pipe.

The outlet of a temporary slope drain should be protected with riprap as required to prevent erosion due to high-velocity outflows. Often this protection will be in the form of a riprap basin of sufficient size to dissipate the outlet flow velocity. This basin should have a diameter of at least 8 feet. It should be specified in any situation where erosion would be a concern, particularly where the 4-foot horizontal pipe section is not feasible or where the outlet channel is at an angle to the pipe outlet. Based upon engineering judgment, the designer may design a riprap energy dissipation basin, as described in Section 10.08.3. In other situations it may be sufficient to ensure that the outlet channel is lined with properly sized riprap.

Temporary slope drains shall be paid for under the following item numbers:

- 203-01, Road & Drainage Excavation (Unclassified), per CY
- 209-02.03 Thru 209-02.07, 8” to 18” Temporary Slope Drain, per LF
- 709-05.06, Machined Rip-Rap (Class A-1), per Ton

10.08.1.6.5 EXAMPLE APPLICATION

Given: A proposed ramp has been designed to have a side slope of 2H:1V and a fill height of 20 feet. The ramp is in normal crown with one 16 foot lane, an outside shoulder 8 feet wide and an inside shoulder 6 feet wide. The ramp is 800 feet long at a profile grade of 2%. The designer has determined that the best erosion prevention and sediment control measure for the ramp is a temporary berm with temporary slope drains.

Find: Determine the required temporary slope drain quantities for the outside shoulder of the 800 foot ramp. For temporary berm calculations refer to Section 10.08.1.7, Temporary Berm (EC-STR-27).

Solution:

Step1: Determine the drainage area: The drainage area includes the 16 foot lane and the 8 foot shoulder for 800 feet. Thus:

$$Area = Width\ x\ Length = (16+8)\times 800 = 19200\ SF = 0.44 \text{ acres}$$

Step2: Determine the size and number of temporary slope drains: According to the table “Temporary Drain Sizes” on Standard Drawing EC-STR-27, the maximum drainage area for a 12 inch diameter pipe is 0.5 acres. Since the area to be drained is 0.44 acres, a single 12 inch temporary drain should be sufficient.

When considering this site, however, it was judged that an 800-foot flow length from the top of the ramp to the temporary drain pipe would be excessive. In particular, given that the slope along the berm will be 2%, there is a possibility that shear stresses exerted by the flow could become excessive. Thus, based upon engineering judgment, it is decided to use two 8 inch slope drains with drainage areas of 0.22 acres each. This will break up the length of the concentrated flow and route the stormwater runoff to established vegetation. Therefore use two 8 inch slope drains spaced 400 feet apart.

Step3: Determine Quantities: The pay items for these temporary slope drains will be:

<u>Item Number 209-02.03, 8” Temporary Slope Drain, per LF</u>

Find the length of the pipe along a 20 foot high 2H:1V slope.

$$Length = \sqrt{(20)^2 + (40)^2} = 44.72 \text{ feet}$$

At the top of the slope, the temporary berm will be constructed at the minimum height of 18 inches. This will provide more than the minimum required cover of 6 inches above the pipe. Given a 2-foot top width and 3H:1V side slopes, the width of the berm at its base will be 11.0

feet. An additional 4 feet will be required in order to extend the pipe into the riprap basin at the bottom of the slope. The total length of pipe required for each drain will therefore be:

$$Length = 44.72 + 11 + 4 = 59.72 \text{ feet}$$

Use 60 LF for each slope drain, therefore the final pipe quantity is:

$$2 \times 60 = 120 \text{ LF}$$

Item Number 709-05.06, Machined Rip-Rap (Class A-1), per Ton

According to Standard Drawing EC-STR-27, the riprap apron should be a minimum of 8 feet in diameter and should be at least 1.5 feet deep. Thus, the volume of riprap required for each apron would be equal to the area of an 8-foot circle multiplied by a depth of 1.5 feet:

$$Apron\,Volume = \pi\left(\frac{8^2}{4}\right)1.5 = 75.40 \text{ CF}$$

In addition to the riprap apron, an additional volume will be needed to form the drainage anchor at the downstream end of the pipe. Based on engineering judgment, the dimensions of the anchors at each pipe were determined to be 2 feet wide by 4 feet long by 1.5 feet high. Thus the volume of stone in each anchor would be:

$$Anchor\,Volume = 2 \times 4 \times 1.5 = 12 \text{ CF}$$

Thus, the total volume of riprap for both drains would be:

$$Total\,Volume = 2(75.40 + 12.0) = 174.8 \text{ CF = 6.5 CY}$$

Per Section 10.04.6.1, convert the volume of computed quantity of machined riprap to Tons:

$$6.5\text{CY} \times 1.75\,Ton/CY = 11.3 \text{ Tons}$$

10.08.1.7 TEMPORARY BERM (EC-STR-27)

Temporary Berm at Top of Fill Slope
Location: SR-73, Sevier County, TN (2004)

10.08.1.7.1 DEFINITION AND PURPOSE

This erosion prevention measure consists of a ridge of compacted soil constructed above, across, or below a sloping, disturbed area. It can be combined with a small ditch or swale to assist in diverting the runoff.

Temporary berms may be used for a number of purposes. However, the three principle uses are to:

- divert storm runoff from upslope drainage areas away from unprotected disturbed areas or slopes to erosion-resistant outlets
- divert sediment laden runoff from a disturbed area to a sediment trap or sediment basin. These diversions will often be located at the base of a disturbed slope
- shorten the flow length on a sloping area, thereby reducing the potential for erosion by diverting storm runoff to an erosion-resistant outlet

10.08.1.7.2 APPROPRIATE APPLICATIONS

Temporary berms are applicable where stormwater runoff must be diverted to protect disturbed areas and slopes or to retain sediment on-site during construction. When used at the top of a slope, the structure provides protection by diverting upland runoff to an acceptable outlet. Often, this will be a temporary slope drain, as described in Section 10.08.1.6. In some situations, these structures may be used at the top of a slope to divert stormwater from an undisturbed area around the disturbed area to prevent additional erosion which could occur due to the increased flows. When used at the base of a slope, the structure protects adjacent and downstream areas by diverting sediment laden runoff to a sediment-trapping facility. Temporary berms may also be used where runoff has the potential to prevent the establishment of vegetation in low areas.

This practice is often more economical than other methods which may be available, as it uses material available on site and can usually be constructed with equipment needed for site grading.

Effective device for diverting runoff from undisturbed and off-site areas around and away from temporary sediment basins and other sediment trapping devices; whereby reducing the required volume of these devices

10.08.1.7.3 LIMITATIONS

Temporary berms may not be used to divert channels or streams. See Section 10.08.1.8, Temporary Diversion Channel for additional information. Additionally, temporary berms should not be used where the drainage area exceeds 1.5 acres.

10.08.1.7.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is not required. However, when temporary berms are utilized, the following standards should be used.

The berm should be at least 18 inches high, and have a top width of at least 2 feet with 2H:1V or flatter side slopes.

In most cases, an 18-inch high berm will be adequate to contain the runoff from an area of 1.5 acres or less for the storm event specified in Section 10.05.1. Where it necessary for a designer to specify a berm greater than 18 inches, it should be designed based on 0.3 feet of freeboard and a settlement of 10%.

Where a temporary berm is employed with a temporary slope drain pipe, the berm should be at least 6 inches above the top of the pipe.

Any trees, brush, stumps or other material which would interfere with the function of the berm should be removed from its alignment and be properly disposed. The temporary berm should be machine compacted and have stable side slopes prior to commencement of major land disturbing activities. Standard Drawing EC-STR-27 provides typical cross sections for diversion berms and swales.

Where the longitudinal (profile grade) slope is greater than 2%, the berm and/or ditch should be stabilized with seeding and mulch, erosion control blankets, or riprap as described in Chapter 5 of this Manual. In general, these structures should be stabilized prior to the start of other construction activities.

Each diversion berm should have an outlet adequate to convey the design flow without experiencing additional erosion. The outlet may be a constructed or natural waterway, a sediment-trapping device or energy dissipator.

Temporary berms shall be paid for under the following item number:

- 203-01, Road & Drainage Excavation (Unclassified), per CY

Items used for the stabilization of temporary berms shall be paid for under their respective item numbers.

10.08.1.7.5 EXAMPLE APPLICATION

Given: A proposed ramp has been designed to have a side slope of 2H:1V and a fill height of 20 feet. The ramp is in normal crown with one 16 feet lane, an outside shoulder 8 feet wide and an inside shoulder 6 feet wide. The ramp is 800 feet long at a profile grade of 2%. The designer has determined that the best erosion prevention and sediment control measure for the ramp is a temporary berm with temporary slope drains.

Find: Determine the required size and quantities for a temporary berm on the outside shoulder of the ramp. For temporary slope drain calculations refer to Section 10.08.1.6.

Solution:

***Step1: Determine the size of temporary berm*:** As determined in Section 10.08.1.6, two 8 inch temporary slope drains spaced at 400 feet will be used at this site. The drainage area at each slope drain will be 0.22 acres. As stated in Section 10.08.1.6, the berm should be at least 6 inches higher than the temporary slope drain pipe. The minimum berm height of 18 inches exceeds this requirement, and will thus be used.

The temporary berm will have a height of 18 inches, a top width of 24 inches, and 3H:1V side slopes. The material for constructing the berm will be obtained by excavating a ditch on the upslope side. Since the 2-year flow from a drainage area of 0.22 acres will clearly be less than the capacity of this ditch, it does not need to be checked for hydraulic capacity.

Step2: Determine Quantities: The pay item for this example is:

<u>Item Number 203-01, Road and Drainage Excavation (Unclassified), per CY</u>

Find the cross-sectional area of the temporary berm. Since it may be considered to be trapezoidal in shape, the area may be computed as:

$$Area = (TopWidth)(Height) + (Slope)(Height^2) = (2)(1.5) + (3)(1.5^2) = 9.75 \text{ SF}$$

The volume required for this berm may then be computed by multiplying the length by the cross sectional area:

$$Volume = 800 \times 9.75 = 7800 \text{ CF}$$

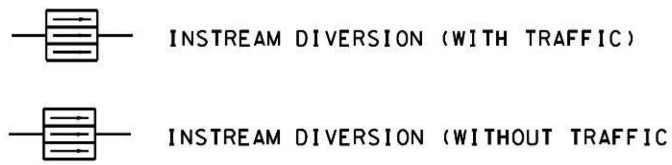
Earth berm ditch blocks will be required at the inlets of the two temporary slope drain pipes. Based on the expected configuration of the site, it is anticipated that these ditch blocks will be 10 feet long. In addition, since they should be at a lower height than the diversion berm, the height of the blocks is determined to be 12 inches. Since these blocks will also have a 24-inch top width and 3H:1V side slopes, the cross sectional area of these blocks will be 5.0 SF. Thus, the volume of the ditch blocks may then be computed as:

$$Volume = 20 \times 5.0 = 100 \text{ CF}$$

Thus, the final quantity for this pay item is:

$$Volume = 7800 + 100 = 7900 \text{ CF} = 292.6 \text{ CY}$$

10.08.1.8 TEMPORARY INSTREAM DIVERSION (EC-STR-30 AND 30A)



Temporary Instream Diversion
Location: Robertson County, TN (2007)

10.08.1.8.1 DEFINITION AND PURPOSE

Instream diversions consist of temporary dikes used to divert the low flows of a stream in order to accommodate the construction of a multiple barrel box culvert, box bridge or slab bridge. Flows are typically diverted into either an existing or newly constructed barrel so that the other barrels can be constructed in the dry. In this way the work can be separated from flowing water so that the release of sediments can be prevented.

10.08.1.8.2 APPROPRIATE APPLICATIONS

Instream diversions may be used where in-stream work is unavoidable for projects where a multiple barrel structure is proposed. With appropriate phasing, it may be utilized for projects where traffic is to be maintained on the roadway during construction. To the extent possible, this measure should be used when low flow conditions are expected.

10.08.1.8.3 LIMITATIONS

None.

10.08.1.8.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is not required.

Appropriate phasing is essential to the successful application of an in-stream diversion. However, the EPSC plans need to include only the symbol shown above for this measure. It will be the responsibility of the contractor to determine the best phasing to accommodate the maintenance of traffic and the means of construction. The construction engineer will give approval of the phasing the contractor plans to use.

Where feasible, an in-stream diversion can be more cost effective than a temporary diversion channel (EC-STR-31 and EC-STR-31A) or a temporary diversion culvert (EC-STR-32). It also has the advantage of being applicable where traffic is to be maintained.

The main disadvantage of this measure as compared to temporary channels or culverts is that this measure is sized based on the low flow of the stream rather than based on the 2-year flood event. Thus, it is much more easily overtopped during periods of increased stream flow. When choosing the method of diversion, the designer should consider the required time for the construction as well as potential consequences should the work area become flooded.

As shown in EC-STR-30A, the overall length of the box structure may be increased for projects in which traffic is maintained on the roadway. Where this is the case, approval for the increased length will be required from the Design Manager. Approval for the increased length will also be required from the Hydraulics Section for sites where the 50-year discharge is greater than 500 cfs.

Standard Drawings EC-STR-30 and 30A require that the height of the diversion be 1 foot above the ordinary flow elevation in the reduced channel width of the stream.

In order to determine the increase in depth which may occur due to a diversion, the following procedure is recommended:

- Estimate the width and flow depth of a representative section of the stream at normal flow from aerial photography, site topography, etc.
- Compute the cross sectional flow area by multiplying the depth times the width.
- Determine the width of flow through the diverted section and divide that area by the flow area determined in the previous step to estimate the depth of flow in the diverted section.
- Compute the wetted perimeter for both the natural cross section and the diverted cross section. If the wetted perimeter of the diverted cross section is greater than the wetted perimeter of the natural cross section, the diverted channel section is too narrow. The diverted section should be redesigned to provide a wider flow width.
- The final height of the diversion will be 1 foot above the diverted flow depth determined above.

The flow line of the diverted section should match as much as possible the existing flow line of the stream. Where excavation is required to achieve the required flow area in the diverted section, the excavation should be to the side instead of increasing the depth.

The standard drawings suggest several types of materials which may be used to construct instream diversions. Several of these materials allow for the incorporation of polyethylene sheeting (6 mil minimum) to increase their effectiveness. For example, placing polyethylene sheeting inside a sand bag berm and covering the jersey barrier with polyethylene sheeting to prevent seepage of water into the work area.

Once the work area has been isolated from the stream by the instream diversion, it should be dewatered by means of pumping. Effluent from this pumping operation should be passed through a sediment filter bag or dewatering structure, as described in Section 10.08.2.

Standard Drawings EC-STR-30 and 30A show a number of other measures which should be used in conjunction with an in-stream diversion, including sediment filter bags, silt fence and silt fence with wire backing. These items are paid for separately from the in-stream diversion and thus should be included in the EPSC quantities as separate items.

Temporary instream diversions shall be paid for under the following item number:

- 209-65.14, Temporary In Stream Diversion, per LF

10.08.1.8.5 EXAMPLE APPLICATION

Given: An existing slab bridge on vertical abutments and a span of 20 feet is to be replaced with a box bridge with three 12-foot spans. A temporary run around will be used to maintain traffic so that the structure can be replaced without traffic. The designer has determined that an instream diversion may be used at this site.

Find: Determine the height and required quantities for the instream diversion.

Solution:

Step 1: Assume a phasing plan: Although it is the responsibility of the contractor to devise a phasing plan, the designer will need to make an educated guess of that the plan in order to estimate lengths for each section of the instream diversions.

Based on the bridge layout plan, it appears that the channel will be shifted somewhat to the west in order to accommodate the increased width of the proposed structure. Thus, it is assumed that the phase 1 instream diversion will extend from the west bank of the channel to the west side of the existing structure. This will maintain flows through the existing structure while allowing the western most barrel of the proposed structure to be built. In phase 2, flows would be diverted into the new barrel of the proposed structure by extending instream diversions from the east bank of the channel to the east side of the new barrel. This will allow the demolition of the existing structure and the construction of the 2 remaining barrels.

Step 2: Determine heights of the instream diversions: Aerial photography of the site is examined in order to estimate the average width of the water surface of the stream in the project area, and this is found to be 25 feet. In this same area, the project survey data indicated that the flow line of the stream is about 1.2 feet below the elevation at the edge of water. Thus, the cross sectional flow area (A) and wetted perimeter (P) of the normal flow are computed as:

$$A = 25\ feet \times 1.2\ feet = 30\ \text{ft}^2$$

$$P = 25\ feet + 2(1.2\ feet) = 27.4\ \text{feet}$$

In phase 1, the width of flow in the diverted section will be 20 feet. Since the cross sectional area of the flow in the diverted section is assumed to be equal to the natural cross sectional flow area, the depth in the diverted section (d_d) is estimated as:

$$d_s = \frac{30\ ft^2}{20\ ft} = 1.5\ \text{feet}$$

Based on this depth, the wetted perimeter of the flow in the diverted section is computed as:

$$P = 20\ feet + 2(1.5\ feet) = 23.0 \text{ feet}$$

Since the wetted perimeter in the diverted section is less than in the natural section, the flow width will be adequate. Thus, the required minimum height of the instream diversion will be 2.5 feet.

In phase 2, the width of the diverted section will be reduced to 12 feet. Using the same process as described above, the depth in the diverted section is found to be 2.5 feet and the wetted perimeter is found to be 17 feet. Again, the wetter perimeter in the diverted section is found to be less than that in the natural section and the height of the instream diversion will be 3.5 feet.

Step 3: Determine quantity of instream diversion: The pay item for a temporary instream diversion is:

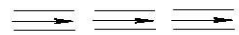
Item Number 209-65.03, Temporary In Stream Diversion, per LF

Based on an inspection of the site layout plan, it is estimated that 25 feet of instream diversion will be needed to connect the west bank of the channel to the existing structure. Since instream diversion will be needed both upstream and downstream of the roadway, this represents a total length of 50 feet. In phase 2, it is estimated that 33 feet of instream diversion will be required to connect the east bank of the channel to the newly constructed barrel of the proposed structure. Again, this will be required on both sides of the roadway, so the length for phase 2 will be 66 feet. Thus, the total quantity including both phases will be 116 feet.

It should be noted that the dewatering operation, silt fence and silt fence with wire backing are all separate items from the instream diversion. Thus, quantities for these items should be calculated under their respective pay item numbers.

10.08.1.9 TEMPORARY DIVERSION CHANNEL (EC-STR-31 AND 31A)

Temporary Diversion Channel
Location: SR-15, Hardin County, TN (2004)



TEMPORARY DIVERSION CHANNEL

10.08.1.9.1 DEFINITION AND PURPOSE

A temporary diversion channel is constructed to convey normal stream flow around in-stream construction such as bridges, culverts, or box culverts. Temporary diversion channels are used to allow in-stream work to be completed in the dry, separate from flowing water. This reduces the amount of sedimentation which could occur in the stream as a result of the construction activity.

10.08.1.9.2 APPROPRIATE APPLICATIONS

A temporary diversion channel should be used where in-stream work is unavoidable and where the diversion will not cross an existing roadway on which traffic must be maintained. To the extent possible, this measure should be used when low flow conditions are expected.

10.08.1.9.3 LIMITATIONS

None.

10.08.1.9.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is required in that the hydrologic and hydraulic analysis of the waterway is necessary in order to determine the typical cross-section and channel transitions required for a temporary diversion channel. For each temporary diversion channel a typical cross-section showing the bottom width, side slopes, depth, and lining type of the temporary diversion channel should be placed in the EPSC Plans. In addition the type of lining and lining limits for the channel transitions should be labeled in the EPSC plan.

The dimensions of a temporary diversion channel should be determined using a 2-year/24-hour storm, and the adequacy of the riprap lining should be checked for the storm frequency specified in Section 10.05.1 to ensure that it will remain stable and will not be overtopped. This will minimize the required size of the diversion channel and lessen the overall environmental impact of the proposed diversion.

Temporary diversion channels should be used for as short a time as possible. All in-stream work should be performed during low flow conditions. Clearing of the stream bed and banks should be kept to a minimum.

The drainage area should be 1280 acres or less. Typically, where the drainage area is larger than this, a multi-cell box culvert would be required, allowing one cell of the structure to be used as the diversion while construction is occurring on the other cell(s). Where this option is available, it is preferred over constructing a temporary diversion channel. See Section 10.08.108 for more information.

Temporary diversion channels should normally be trapezoidal in shape. The bottom width of the temporary diversion channel should be as equal as possible to the bottom width of the natural channel. The side slopes of the diversion should be 2H:1V or flatter. In no case should the diversion side slopes be steeper than the natural side slopes.

Standard Drawing EC-STR-31A provides a procedure for determining the required depth and freeboard of the diversion channel.

All temporary diversion channel linings should utilize geotextile fabric (Type III). This material will either form the liner itself, or be used in conjunction with riprap, as described below. The geotextile fabric should extend to the top of the bank of the diversion channel and be entrenched there as shown in Standard Drawing EC-STR-31. This fabric should meet the requirements of the standard specification for geotextiles, AASHTO designation M-288, Erosion Control.

On streams with intermittent flows and where the flow velocity at the 2-year design discharge is less than 2.5 fps, geotextile fabric alone may be used as the diversion channel liner. On streams with a constant base flow or where the flow velocity at the design discharge is greater than 2.5 fps, riprap should be placed on top of the geotextile to form the lining. The class of riprap may be selected based on the flow velocity as described in Section 5.04 of this Manual. For bedrock streams, geotextile fabric and riprap will only be required on the sides of the temporary diversion channel.

Where riprap is used it should be placed to at least the minimum thickness provided in the TDOT Standard Specifications. Standard Drawing EC-STR-31A should be used to determine the riprap depth. The diversion channel should be over-excavated such that the top of the riprap layer will be at the required ditch grade.

Silt fence with wire backing should be placed at the top of both banks of the diversion channel in order to filter sediment from runoff entering the channel. This silt fence should be entrenched in the same trench as the geotextile used for the lining.

Riprap lined transitions should be placed at the two transitions between the natural channel and the temporary diversion channel. These transitions should be designed in accordance with Chapter 5 of this Manual.

Once the work area has been isolated from the stream by the temporary diversion, it may be dewatered by means of pumping. Effluent from this pumping operation should be passed through a sediment filter bag or dewatering structure, as described in Section 10.08.2.

Temporary diversion channels shall be paid for under the following item numbers:

- 209-65.03, Temporary Stream Diversion, per LF
- 709-05.06, Machined Riprap (Class A-1), per Ton
- 740-10.03, Geotextile (Type III) (Erosion Control), per SY

Dewatering structures, sediment filter bags, and silt fence with backing shall be paid for according to their respective standard drawing. Temporary plugs shall be paid for under their respective item numbers.

10.08.1.9.5 EXAMPLE APPLICATION

Given: The Department is designing a proposed roadway on new alignment in rural Shelby County. The roadway consists of two 12 foot lanes, with 6 foot shoulders. The designer has designed a 12 foot × 4 foot box culvert that is 100 foot long for a small stream which crosses the project. The designer has determined that there is a need for a diversion channel. The drainage area at the site is 120 acres and the stream slope is 0.5%.

Find: Determine the required size and quantities of a temporary diversion channel for the construction of the proposed box culvert.

Solution:

Step 1: Determine the design flow rate: As shown on Standard Drawing EC-STR-31A, Shelby County is located in Hydrologic Area 4. Thus, the design flow rate is interpolated from the table “ K Values for Temporary Diversion Ditch Depth, Hydrologic Area 4 ” on that Standard Drawing. Given a drainage area of 120 acres, the flow rate is found to be 134.9 cfs.

Step 2: Determine design of the temporary diversion channel: Based on examination of the plans, it is determined that the existing channel bottom is approximately 6 feet wide. Thus, the proposed diversion channel will also have a bottom width of 6 feet.

The procedure to determine the depth of flow in the proposed diversion channel provided on Standard Drawing EC-STR-31A may be applied as follows: Given a drainage area of 120 acres and a site slope of 0.5%, a K-value of 1907.6 is interpolated from the table for Hydrologic Area 4. Using the table “Parameters for Depth Equation” on Standard Drawing EC-STR-31A, linear interpolation is again used to determine an “A” value of -0.796 and a “B” value of 4.320. The depth is then computed from:

$$Depth = A \times \ln(Bottom\,Width) + B = -0.796 \times \ln(6) + 4.320 = 2.89 \text{ feet}$$

The temporary diversion channel will be provided with 2H:1V side slopes. Thus, the cross sectional flow area at this depth may be computed from:

$$Area = (Bottom\,Width)(Depth) + z\left(Depth^2\right) = (6)(2.89) + 2\left(2.89^2\right) = 34.1 \text{ SF}$$

The design flow velocity may then be computed from:

$$V = \frac{Q}{A} = \frac{134.9}{34.1} = 3.96 \text{ fps}$$

Since the design velocity is greater than 2.5 fps, but less than 5 fps, machined riprap Class A-1 on geotextile should be used to form the temporary channel lining. Based on the TDOT Standard Specifications, the minimum depth of this class of riprap is 18 inches, which will be sufficient for this design.

The required height of the riprap is determined based on the design flow depth, plus the required freeboard. Since the flow depth is greater than 1 foot, the freeboard will be 1 foot, for a total riprap height of 3.9 feet. The overall depth of the channel from natural ground to the flow line will be 4.0 feet.

Step 3: Design the transitions between the temporary and natural channels: The main portion of the proposed diversion channel will be 100 feet long in order to match the length of the proposed permanent structure. However, since the diversion channel is located to one side of the permanent structure, additional channel length will be necessary to connect the main portion of the diversion channel to the natural stream channel. Based on inspection of the site layout, it is determined that these transitions should be 30 feet long at each end of the channel, and that they should have a radius of curvature of 25 feet. Since the velocity at the design flow rate is less than 5 fps, machined riprap Class A-1 will be suitable for these transitions.

From Chapter 5 of this Manual, the riprap transition lining should extend past the ends of the curved transitions. Since the radius of curvature for these transitions is more than 3 times the bottom width of the channel, the downstream riprap should extend 1.5 times the channel bottom width, or 9 feet, from the end of the diversion channel. In the same way, the upstream riprap should extend 1.0 times the channel bottom width, or 6 feet from the end of the diversion channel.

Step 4: Determine quantities of temporary diversion channel: Figure 10EP-9 presents a typical cross section through the temporary diversion channel and will serve as an aid in computing the required quantities. The pay items for this proposed temporary diversion channel include:

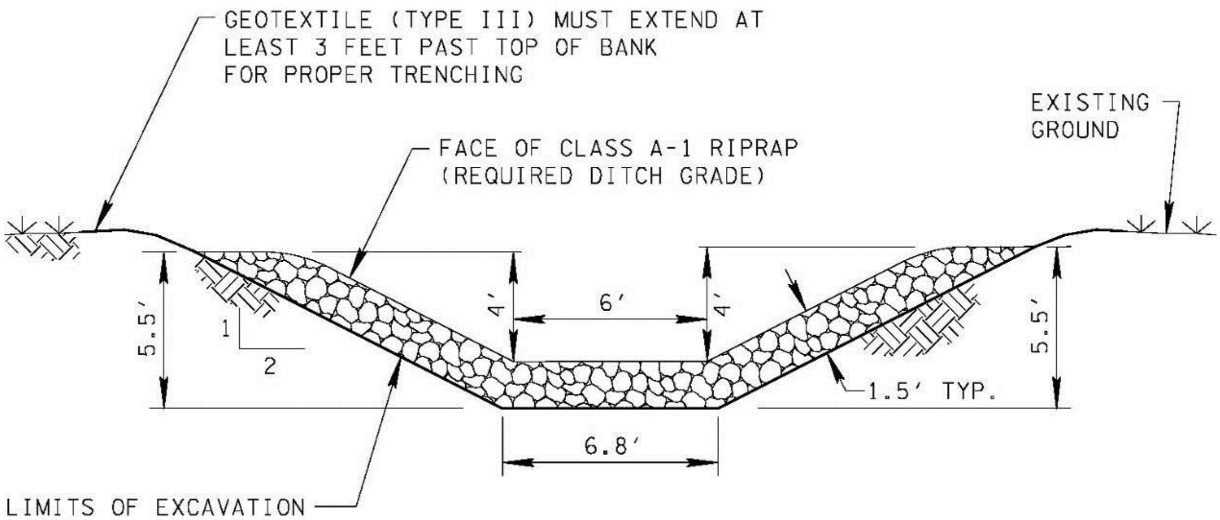


Figure 10EP-9
Cross Section of Temporary Diversion Channel

Item Number 209-65.03, Temporary Stream Diversion, per LF

As discussed in Step 3, the total length of channel to be excavated will be the 100-foot length of the main diversion channel, plus two 30-foot transitions, for a final total quantity of 160 feet.

Item number 209-08.02, Temporary Silt Fence (With Backing), per LF

Silt fence with wire backing is required along both sides of the entire length of the temporary diversion channel. Thus:

$$Length = 2(160) = 320 \text{ feet}$$

It is also necessary to place the silt fence with wire backing along the riprap transitions where they extend into the existing creek:

$$Length = 2(6) + 2(9) = 30 \text{ feet}$$

This yields a final total quantity of 350 feet.

Item number 709-05.06, Machined Rip-Rap (Class A-1), per Ton

To compute the required riprap quantity, the cross sectional area of the riprap layer will be multiplied by the length of the layer along the channel. The cross sectional area, in turn, will be computed based on the average lengths of the sides and bottom of the layer. Based on inspection of Figure 10EP-9, the average height of the riprap layer may be computed as:

$$Average\,Height = \left(\frac{4.0 + 5.5}{2}\right) = 4.75 \text{ feet}$$

Thus, the average length along one side of the trapezoid will be:

$$Length_{side} = \sqrt{4.75^2 + (2 \times 4.75)^2} = 10.6 \text{ feet}$$

The average bottom width may be computed as:

$$Length_{bottom} = \left(\frac{6.0 + 6.8}{2}\right) = 6.4 \text{ feet}$$

Thus, the cross sectional area of the riprap may be computed as the total of these lengths times the layer thickness of 18 inches:

$$Area = (6.4 + 10.6 + 10.6)(1.5) = 41.4 \text{ SF}$$

In computing the volume of excavation, above, a length of 160 feet was used, which represents the length of the main channel plus the length of the two transitions. However, the area of the riprap will be extended into the natural channel a distance of 6 feet on the upstream end, and 9 feet on the downstream end. Thus, the total length of riprap is 15 feet longer than the length used to compute excavation, or 175 feet. The volume of riprap required is thus computed from:

$$Volume = (41.4)(175) = 7245 \text{ CF} = 268.3 \text{ CY}$$

$$268.3\text{CY} \times 1.75\,Ton/CY = 469.6 \approx 470 \text{ Tons}$$

<u>Item number 740-10.03, Geotextile (Type III) (Erosion Control), per SY</u>

Since the geotextile will be placed on the excavated channel bottom before the riprap is placed, the quantity for this item will be computed based on the total cross sectional length of the excavated channel from top of bank to top of bank. As shown in Figure 10EP-9, the total excavated height of the channel will be 5.5 feet. Thus, the length of one side of the trapezoid will be:

$$Length_{side} = \sqrt{5.5^2 + (2 \times 5.5)^2} = 12.3 \text{ feet}$$

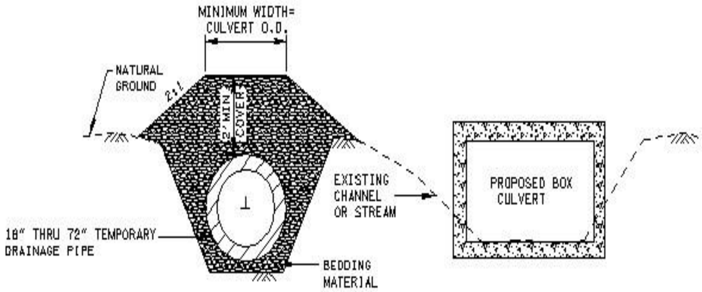
As stated above, the bottom width of the excavated channel will be 6.8 feet. In addition, it will be necessary to include 3 feet of additional length on each side of the channel in order to accommodate the trenching required for the installation of the fabric. Thus the total cross sectional length will be:

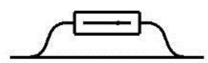
$$Cross\,Sectional\;Length = 6.8 + 2(12.3) + 6 = 37.4 \text{ feet}$$

The final quantity of geotextile may then be computed by multiplying the cross sectional length times the length of riprap along the channel:

$$Area = 37.4 \times 175 = 6545 \text{ SF} = 727 \text{ SY}$$

10.08.1.10 TEMPORARY DIVERSION CULVERT (EC-STR-32)





TEMPORARY DIVERSION CULVERT
(DESCRIBE - NUMBER & SIZE)

Temporary Diversion Culvert
(Photograph not currently available)

10.08.1.10.1 DEFINITION AND PURPOSE

A temporary diversion culvert is generally constructed under an existing roadway to convey stream flow around in-stream construction such as bridges, culverts, or box culverts.

Temporary diversion culverts are used to allow in-stream work to be completed in the dry, separate from flowing water. This reduces the amount of sedimentation which could occur in the stream as a result of the construction activity. These structures are different than temporary culvert crossings in that they are intended to allow continued access on a public roadway, and are backfilled with compacted granular material instead of riprap.

10.08.1.10.2 APPROPRIATE APPLICATIONS

A temporary diversion culvert is usually used where in-stream work is unavoidable and where the diversion crosses an existing roadway on which traffic must be maintained. To the extent possible, this measure should be used when low flow conditions are expected. Temporary diversion culverts should be used for as short a time as possible.

Standard Drawing EC-STR-32 provides information on two types of temporary diversion culverts. The first is a straight pipe which is connected to the natural stream by means of excavated channel transitions. The second type utilizes pipe elbows to connect the structure to the existing channel.

10.08.1.10.3 LIMITATIONS

Where pipe elbows are employed, the structure should be limited to a single pipe.

10.08.1.10.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is required in that the hydrologic and hydraulic analysis of the waterway is necessary in order to determine the temporary drainage pipe size and channel transitions required for a temporary diversion culvert. For each temporary diversion culvert the diameter and length of temporary drainage pipe should be placed on the EPSC plans. The designer shall provide culvert sections in the plans. In addition, when channel transitions are used, the type of lining and lining limits for the channel transitions should be labeled in the EPSC plans.

Temporary diversion culverts should be designed using the storm frequency specified in Section 10.05.1. At a site that involves an Exceptional Tennessee Water or sediment-impaired stream, the diversion pipe (culvert) shall be sized to convey the 5-year peak flow in the stream.

The table “Temporary Diversion Culvert Selection” on Standard Drawing EC-STR-32 may be used to select the pipe size. It should be noted that this table is based upon allowing a 2.5-foot increase in water surface elevation for the design flow rate, as compared to the water surface elevation without the culvert. The designer should include a culvert section for the temporary culvert in the project plans.

The drainage area should be 1280 acres or less. Typically, where the drainage area is larger than this, a multi-cell box culvert would be required, allowing one cell of the structure to be used as the diversion while construction is occurring on the other cell. Where this option is available, it is preferred over constructing a temporary diversion culvert. See Section 10.08.108 for more information.

Where excavated channel transitions are employed, they should normally be trapezoidal in shape. The bottom width of the channel transition should be equal to the bottom width of the natural channel. The side slopes of the transition should be 2H:1V or flatter. In no case should the side slopes be steeper than the natural side slopes.

Excavated channel transitions should be lined with riprap on geotextile fabric (Type III). Guidelines for the selection of the riprap class may be found on the table “Temporary Diversion Culvert Selection” on Standard Drawing EC-STR-32.

Excavated channel transition linings should utilize geotextile fabric (Type III). The geotextile fabric should extend to the top of the bank of the diversion channel and be entrenched there as shown in Standard Drawing EC-STR-31. This fabric should meet the requirements of the standard specification for geotextiles, AASHTO designation M-288, Erosion Control.

Riprap should be placed to at least the minimum thickness provided in the TDOT Standard Specifications. The transition channel should be over-excavated such that the top of the riprap layer will be at the required ditch grade. At a site that involves Exceptional Tennessee Waters or a sediment-impaired stream, the diversion pipe (culvert) shall be sized to convey the 5-year peak flow in the stream.

The excavated channel transition upstream of the temporary diversion culvert should extend into the natural channel as recommended in Chapter 5 of this Manual. The transition on the downstream side of the culvert should be consistent with the guidance provided in Chapter 6 of this Manual.

Silt fence with wire backing should be placed at the top of both banks of the transition channels in order to filter sediment from runoff entering the stream. This silt fence should be entrenched in the same trench as the geotextile used in the lining.

Where elbows are used to connect the pipe to the natural stream, the upstream and downstream ends of the culvert should be anchored to the streambed by means of sandbag plugs. The tops of the sandbag plugs should be at least as high as the natural channel banks, or high enough to provide two layers of sandbags on top of the temporary culvert, whichever is greater.

Where sandbag plugs are employed, the upstream pipe anchor should include a layer of polyethylene sheeting (6 mil. minimum) in order to provide a more water-tight seal. The polyethylene sheeting should be field-fitted around the pipe.

The minimum cover on a temporary diversion culvert should be 24 inches, measured from the bottom of the pavement over the culvert to the outside of the pipe.

Once the work area has been isolated from the stream by the temporary diversion, it may be dewatered by means of pumping. Effluent from this pumping operation should be passed through a sediment filter bag or dewatering structure as described in Sections 10.08.2.2 and 10.08.2.1, respectively.

Temporary diversion channels shall be paid for under the following item numbers:

- 203-01, Road & Drainage Excavation (Unclassified), per CY
- 209-09.01, Sandbags, per Bag
- 209-20.03, Polyethylene Sheeting (6 Mil. Minimum) per SY
- 621-03.02 thru 621-03.11, 18” to 72” Temporary Drainage Pipe, per LF
- 709-05.06, Machined Rip-Rap (Class A-1), per Ton
- 709-05.08, Machined Rip-Rap (Class B), per Ton
- 709-05.09, Machined Rip-Rap (Class C), per Ton
- 740-10.03, Geotextile (Type III) (Erosion Control), per SY

10.08.1.10.5 EXAMPLE APPLICATION

Given: The Department is designing a culvert replacement on an existing roadway which crosses a small stream in rural southwest Tennessee, Fayette County (CN=75). The roadway consists of two 12-foot lanes, with 6 foot shoulders. The replacement structure will consist of a 12 foot × 4 foot box culvert, 100 foot long. In order to allow this project to be constructed in the dry, a temporary diversion culvert will be used. The drainage area at the site is 120 acres with a time of concentration of 0.70 hr and the stream slope is 0.5%. The area is Hydrologic Area 4.

Find: Determine the required design and quantities for a temporary diversion culvert for the construction of the proposed box culvert.

Solution:

Step 1: Determine the design flow rate: The design flow rate should be based on the 2-Year, 24-hour storm. Since the drainage area at this site is greater than 100 acres, the TR-55 Graphical Peak Discharge Method will be used. The design flow rate is computed as follows:

- For a 2-Year, 24 Hour storm the Rainfall, P = 3.98” (Table 4A-5)
- Initial abstraction, I_a = 0.667” (Table 4-1, Technical Release 55)
- Compute I_a/P

$$\frac{I_a}{P} = \frac{0.667}{3.98} = 0.1676$$

- Unit Peak Discharge, q_u = 440 csm/in (Exhibit 4-II, Technical Release 55)
- Runoff, Q

$$S = \frac{1000}{CN} - 10 = \frac{1000}{75} - 10 = 3.333 \text{ (Equation 2-4, Technical Release 55)}$$

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} = \frac{(3.98 - 0.2(3.33))^2}{(3.98 + 0.8(3.33))} = 1.653\text{"} \text{ (Equation 2-3, TR 55)}$$

- Pond and Swamp Adjustment Factor, F_p = 1.0 (Table 4-2, Technical Release 55)

The 2-year design flow rate is then computed as:

$$q_p = q_u A_m Q F_p = (440)(0.1875)(1.653)(1.0) = 136.4 \text{ cfs (Use 136 cfs)}$$

Step 2: Select culvert size and diversion type: Based on the table “Temporary Diversion Culvert Selection” on Standard Drawing, EC-STR-32, the smallest single pipe capable of conveying the 2-year flow rate is a 60-inch pipe. Since the site offers 8 feet of clearance between the existing channel bottom and the profile grade of the roadway, there will be sufficient cover, and this size will be acceptable.

Due to the diameter of the selected pipe, it is judged that the connection between the diversion culvert and the natural channel should be provided by means of excavated channel transitions, rather than by providing pipe elbows.

Step 3: Design the upstream channel transition: Based on examination of the plans, it is determined that the existing channel bottom is approximately 6 feet wide. Thus, the excavated channel transitions will also have a bottom width of 6 feet. It is also determined that the average depth of the channel transition will be 4 feet, with 2H:1V side slopes. Based on inspection of the site layout, it is determined that this transition should be 30 feet long and that it should have a radius of curvature of 25 feet.

Based on Section 5.05.7 of this Manual, riprap erosion protection should extend past the end of the curved channel transition into the natural channel. Since the radius of curvature for this transition is more than 3 times the bottom width, the upstream riprap should extend 1.0 times the channel bottom width, or 6 feet from the end of the diversion channel. Thus, the total length of this transition will be 36 feet.

The riprap recommendation provided on the table “Temporary Diversion Culvert Selection” on Standard Drawing, EC-STR-32, is based on the culvert outlet velocity. However, upstream of the culvert, the velocity will be lower. Thus, it is decided to compute the upstream flow velocity in order to check the required class of riprap. It is first assumed that the upstream channel lining will consist of machined riprap Class A-1, and the procedure provided in Chapter 5 of this Manual is used to determined normal depth for the design flow rate. Based on a trapezoidal cross section with a 6-foot bottom width, 2H:1V side slopes, and stream slope of 0.005 ft/ft, it is found that the normal depth would be 2.86 feet, at a velocity of 4.07 fps. Since the velocity at the design flow rate is less than 5 fps, machined riprap Class A-1 will be suitable for this transition.

Step 4: Design the downstream channel transition: As recommended in the table "Temporary Diversion Culvert Selection" on Standard Drawing, EC-STR-32, machined riprap Class B will be used downstream of the temporary culvert. The required length of the riprap apron will be determined using the procedure provided in Chapter 6 of this Manual.

The main portion of the proposed diversion channel will be 100 feet long in order to match the length of the proposed permanent structure. However, since the diversion channel is located to one side of the permanent structure, additional channel length will be necessary to connect the main portion of the diversion channel to the natural stream channel. Based on inspection of the site layout, it is determined that these transitions should be 30 feet long at each end of the channel, and that they should have a radius of curvature of 25 feet.

From Chapter 5 of this Manual, the riprap transition lining should extend past the ends of the curved transitions. Since the radius of curvature for these transitions is more than 3 times the bottom width of the channel, the downstream riprap should extend 1.5 times the channel bottom width, or 9 feet, from the end of the diversion channel. In the same way, the upstream riprap should extend 1.0 times the channel bottom width, or 6 feet from the end of the diversion channel.

The first step of designing the riprap apron is to determine the flow depth and velocity at the culvert outfall. To determine the culvert outlet conditions, it is necessary to compute the tailwater depth, as well as the critical and normal flow depths in the culvert.

The tailwater depth is computed as the normal depth of flow in the channel downstream of the culvert. Although this channel will have the same cross section and slope as the upstream channel, it will be lined with machined riprap Class B, which has a higher Manning's n-value. Using the procedures provided in Chapter 5, the normal depth is found to be 2.97 feet, and the velocity of flow is found to be 3.85 fps.

Since the flow capacity of a 60-inch corrugated metal culvert (n-value = 0.024) at a slope of 0.005 is 99.8 cfs, the normal flow depth is assumed to be equal to the culvert diameter of 5 feet. Interpolating from Table 6A-7, in the appendix to Chapter 6 of this Manual, the critical depth in the pipe is determined to be 3.34 feet. Since the tailwater depth is less than both the normal and critical flow depths, the flow at the culvert outfall will be at critical depth.

Before proceeding with the design of the riprap apron, the ratio of the culvert outlet depth (y_o) to the tailwater depth (TW) should be checked as noted in Chapter 6:

$$\frac{TW}{y_o} = \frac{2.97}{3.34} = 0.89$$

Since this ratio is greater than 0.75, a riprap apron may be used at this site.

The next step in designing the riprap apron is to determine the flow velocity at the culvert outlet. To accomplish this, the ratio of the outlet depth to the culvert diameter is computed:

$$\frac{y_o}{D} = \frac{3.34}{5.0} = 0.668$$

Using this ratio with Table 6A-11 in the Appendix to Chapter 6 yields a value of 0.710 for the ratio of the part-full flow area to the culvert end area, A_{go}/A. Thus, the flow area at the culvert outlet depth may be computed from:

$$A_o = \left(\frac{A_o}{A}\right)\pi\left(\frac{D_2}{4}\right) = (0.710)\pi\left(\frac{5^2}{4}\right) = 13.94 \text{ SF}$$

The outlet velocity, V_O, may then be computed from:

$$V_o = \frac{Q}{A} = \frac{136.0}{13.94} = 9.76 \text{ fps}$$

The effective diameter at the outflow D_{eff}, is computed from:

$$D_{eff} = \left(\frac{4A_o}{\pi}\right)^{0.5} = \left(\frac{4[13.94]}{\pi}\right)^{0.5} = 4.21 \text{ feet}$$

With this information it is possible to use Figure 6A-10 in the Appendix to Chapter 6 to determine the required length of the apron. First, the ratio of the natural channel velocity to the culvert outlet velocity (V_n/V_o) is computed (this ratio is called V_L/V_o in the figure). However, the minimum natural channel velocity for this analysis is 5.0 fps; thus, the ratio is computed as:

$$\frac{V_n}{V_o} = \frac{5.0}{9.76} = 0.51$$

Figure 6A-10 then yields a value of approximately 12 for the ratio of the apron length to the effective diameter (L_a/D_{eff}). Multiplying this ratio by the effective diameter of 4.21 feet yields an apron length of 51 feet.

It should be noted that the channel transition between the temporary diversion culvert and the natural channel is 30 feet long. Based on the criteria presented in Section 5.05.7 of this Manual, riprap scour protection should extend 9 feet past the end of the curved transition, which represents a total length of 39 feet, which is considerably less than the required riprap apron length computed above. Further, the riprap apron would extend a distance of 21 feet into the natural channel, which may complicate the environmental review of the project. Thus, it is judged that a 51-foot riprap apron is not acceptable for this project.

As an alternative to using a riprap apron, a riprap basin energy dissipator is considered. Although the design of the basin is left to the reader, it is determined that the basin will have a length of 20 feet, and a width at the widest point, from outside to outside of the riprap, of 45 feet. Inspection of the project plans indicates that this basin will fit into the project site, and the riprap basin is chosen as the preferred method for providing erosion protection downstream of the culvert outfall.

Step 5: Determine quantities for the temporary diversion culvert: The pay items for the proposed temporary diversion channel include:

Item Number 203-01 Road and Drainage Excavation (Unclassified), per CY

In order to organize the computations, the excavation for this project will be considered in 4 parts: excavation under the existing roadway for the temporary diversion culvert; excavation of the upstream channel transition; excavation for the proposed riprap basin energy dissipator and excavation for the downstream channel transition.

Since excavation for a pipe culvert is included in the cost of the culvert, and not as a separate item, a quantity is not computed for the excavation for the temporary diversion culvert.

Upstream of the temporary diversion culvert, the proposed channel transition will have a 6-foot bottom width, an average depth of 4 feet and 2H:1V side slopes. However, to accommodate the required 18-inch depth of the riprap layer, the depth of excavation will be 5.5 feet, with a base width of 6.8 feet. Thus, the cross sectional area of the excavation may be computed as:

$$Area = (Bottom\,Width)(Depth) + 2\left(Depth^2\right) = (6.8)(5.5) + 2\left(5.5^2\right) = 97.9 \text{ SF}$$

Multiplying this cross sectional area by the channel transition length of 30 feet yields a volume of 2937 CF.

Downstream of the temporary diversion culvert, the channel diversion will have the same dimensions as the upstream transition, and will thus have a cross sectional area of 97.9 SF. Since it is to be located downstream from the riprap basin energy dissipator, the flow velocities on this portion of the transition should be sufficiently low to allow it to be constructed with machined riprap Class A-1. Further, since the riprap basin energy dissipator will occupy the first 20 feet of the channel length, this cross sectional area can be applied only over the remaining 10-foot length. Thus, the volume this portion of the excavation will be 979 CF.

The riprap basin energy dissipator will be constructed from Class B riprap, which requires a minimum layer thickness of 2.5 feet. Given that the average channel depth will be 4 feet, the bottom of the excavation for the basin will be 6.5 feet below grade. It has been determined that the plan area of the basin at the bottom of the excavated area will be 254.5 SF. In addition, the plan area of the basin at grade will be 1294.5 SF. The average of these two areas is:

$$Average\,Plan\,Area = \frac{254.5 + 1294.5}{2} = 774.5 \text{ SF}$$

Multiplying this average plan area by the excavated depth of 6.5 feet yields an excavated volume of 5034 CF.

Thus, the final quantity for excavation may be computed as:

$$Volume = 2937 + 979 + 5034 = 8950\,CF\left(\frac{1CY}{27CF}\right) = 331.5 \text{ CY}$$

<u>Item number 709-05.06, Machined Rip-Rap (Class A-1), per Ton</u>

As stated above, the channel transitions upstream of the temporary diversion culvert and downstream of the riprap basin energy dissipator will be lined with machined riprap Class A-1. To compute the required riprap quantity, the cross sectional area of the riprap layer will be multiplied by the lengths of the channel transitions in these two areas. The configuration of the riprap lining will be essentially the same as shown in Figure 10EP-9. The area was computed to be 40.8 square feet.

The lengths of the channel transitions will be 30 feet upstream of the temporary diversion culvert and 10 feet downstream of the riprap basin. However, the area of the riprap will be extended into the natural channel a distance of 6 feet on the upstream end, and 9 feet on the downstream end. Thus, the length of the riprap upstream of the culvert will be 36 feet and downstream of the riprap basin it will be 19 feet, making the total length of the two linings 55 feet. The volume of riprap required is thus computed as:

$$Volume = (40.8)(55) = 2244 \text{ CF} = 83.1 \text{ CY}$$

Based on Section 10.04.6, the computed volume may be converted to tons as:

$$83.1\text{CY} \times 1.75\,Ton / CY = 145.4 \text{ Tons}$$

<u>Item number 709-05.08, Machined Rip-Rap (Class B), per Ton</u>

Based on the exit velocity from the temporary diversion culvert for the design flow rate, the riprap basin energy dissipator is to be constructed with machined riprap Class B. In the quantity computations for excavation presented above, the plan area of this basin was presented at the natural ground surface level. However, since the total depth of the basin will be 4.4 feet (the reader can verify this based on Figure 9-9 in Chapter 9 of this Manual), the top of the basin will be above the existing grade and will represent a plan area of 1372.5 SF. The thickness of the riprap layer will be 2.5 feet. Thus, the volume may be computed from:

$$Volume = 1372.5 \times 2.5 = 3431.3\,CF = 127.1 \text{ CY}$$

Based on Section 10.04.6, the computed volume may be converted to tons as:

$$127.1\text{CY} \times 1.75\,Ton/CY = 222.4 \approx 223 \text{ Tons}$$

<u>Item number 209-08.02, Temporary Silt Fence (with Backing), per LF</u>

Silt fence with wire backing is required along both sides of the channel transitions. However, the top of the riprap basin energy dissipator will be above existing grade and earth will be bermed up around the structure to support the riprap layer. This berm will prevent runoff from the site from entering the stream. Thus, silt fence will be required only on the 36-foot length of the upstream transition channel and along the 19-foot transition length downstream of the riprap basin. The final quantity of silt fence required may therefore be computed as:

$$Length = 2(36 + 19) = 110 \text{ feet}$$

Item number 621-03.09: 60" Temporary Drainage Pipe, per LF

The length of the temporary diversion culvert will be the same as the length of the permanent culvert. Thus, the final quantity for this item will be 100 LF.

Item number 740-10.03, Geotextile (Type III) (Erosion Control), per SY

To organize the quantity computations for this item, the geotextile required for the channel transitions will be considered separately from the geotextile for the riprap basin energy dissipator.

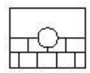
As noted above, the two channel transitions will have essentially the same dimensions as the channel shown in Figure 10EP-8. Thus, the cross sectional length of the fabric across the channel transitions will be the same as the length computed for that problem, or 37.4 feet. It should be noted that this includes extra length at the channel top of banks for trenching the material into the existing ground. Also as noted above, the lengths of the channel transitions will be 36 feet and 19 feet, for a total of 55 feet. Thus, the area of geotextile required for the transitions will be:

$$Area = (37.4)(55) = 2057 \text{ SF}$$

The plan area of the riprap basin at its top was determined to be 1372.5 SF. Thus, the final quantity of geotextile required will be:

$$Area = 2057 + 1372.5 = 3429.5 \text{ SF = 381 SY}$$

10.08.1.11 SUSPENDED PIPE DIVERSION (EC-STR-33 & 33A)



Suspended Pipe Diversion
Source: NCDOT (2003)

10.08.1.11.1 DEFINITION AND PURPOSE

This erosion prevention measure consists of a temporary drainage pipe suspended above the floor of a box culvert or slab bridge. These pipes are used to isolate the construction of an extension to the culvert, or other similar work, from the flow of a stream. This allows the extension to be constructed in the dry and prevents potential sedimentation in the stream. A plug composed of sandbags or other suitable materials serves to isolate the end of the suspended pipe diversion which is inside the culvert. The end of the suspended pipe diversion, which is outside of the culvert, is isolated by means of a berm composed of sandbags or other suitable materials.

10.08.1.11.2 APPROPRIATE APPLICATIONS

These suspended pipe diversion are typically used for the extension of an existing box culvert or slab bridge. Suspended pipe diversions allow traffic to be maintained on the roadway where a box culvert or bridge is being extended as part of a project. The construction of a new culvert or the complete replacement of an existing structure will usually make use of a temporary diversion channel or a temporary diversion culvert.

10.08.1.11.3 LIMITATIONS

This measure should be used where the design flow can be conveyed through a single pipe which is small enough to leave sufficient work room between the pipe and the walls of the culvert. This measure may be adapted for multi-cell culverts by using a single pipe for each cell.

Suspended pipe diversions should not be used where adverse impacts might be caused by water ponding upstream of the pipe and sandbag plug.

10.08.1.11.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is required in that the hydrologic and hydraulic analysis of the waterway is necessary in order to determine the temporary drainage pipe size required for a suspended pipe diversion. For each suspended pipe diversion, the diameter and length of temporary drainage pipe should be placed in the EPSC plans.

The maximum allowable drainage area for this practice is 1280 acres. In general, this measure should be designed using the storm frequency specified in Section 10.05.1. At a site that involves Exceptional Tennessee Waters or a sediment-impaired stream, the diversion pipe (culvert) shall be sized to convey the 5-year peak flow in the stream. For intermittent streams, or very small streams, or sites where the construction period is expected to be brief, the designer may specify the optional flexible pipe diversion using a pump as shown on EC-STR-33A.

The temporary drainage pipe size may be selected based on the table “Temporary Diversion Culvert Selection” on Standard Drawing EC-STR-32.

Pipe supports may be constructed of sandbags, concrete blocks, wooden frames, or any other material sufficient to support the weight of the pipe flowing full. Supports should “cradle” the pipe to prevent rolling during the construction of the box culvert extension. The pipe must be supported at all joints and at a span no wider than specified in the table “Maximum Span for Pipe Supports” on the standard drawing.

Where the sandbag plug inside the culvert is at the upstream end of the suspended pipe diversion, it should be constructed in a pyramid configuration as shown in the standard drawing. This will ensure that the structure has sufficient weight to resist the pressure of water ponded on one side of the plug. To allow for an overflow in a large rainfall event, the top of the sandbag plug should be equal to 3/4ths of the rise of the box. The plug should also incorporate a 6 mil polyethylene sheet to help provide a water-tight seal.

Where the plug is at the downstream end of the suspended pipe diversion, the configuration of the sandbag structure need only be sufficient to support the weight of the pipe. However, its height should still be equal to $3/4^{ths}$ of the culvert rise, and it should still span the entire culvert width.

The sandbag berm outside of the box culvert should be tied into high ground on either side of the stream. Where high ground is not sufficiently near to the stream channel, the berm may be curved to tie into the roadway embankment. The portion of the sandbag berm which is in the channel should incorporate a 6 mil (minimum) polyethylene liner to provide a more water-tight seal. This liner should be included whether or not the berm is at the upstream end of the pipe. Portions of the berm outside of the channel will normally not require this liner. Beyond the limits of the channel, a compacted earthen berm may be utilized as a substitute for sandbags. Where a compacted earthen berm is utilized, temporary seeding with mulch shall be specified to stabilize the berm and establish temporary vegetation. The berm shall also be provided with silt fence with wire backing or other suitable measures down-grade to prevent eroded sediment from the disturbed area from entering the stream.

Where the sandbag berm is at the upstream end of the suspended pipe diversion, it should be constructed to a level sufficient to contain the design flood. A sufficient number of sandbags should be placed on top of the pipe to stabilize the inlet during periods of high flow.

Where the sandbag berm is at the downstream end of the suspended pipe diversion, the top of the berm should be no higher than the top of the sandbag plug in the culvert. An emergency overflow should be provided in the berm, directly in line with the channel. This overflow should be equal in width to the box culvert and be one to two bags lower than the rest of the berm.

The quantity of sandbags needed to construct the berm may be estimated from Table 10EP-2. The number of sandbags required for other sandbag structures may be estimated based on an average value of 0.75 cubic foot per sandbag.

Sandbags are typically polyethylene or burlap bags. The dimensions of a filled sandbag can be variable, depending on the method used to fill and tie the bag. For the sake of simplicity, the average length of a filled bag may be assumed to be 18 inches, width may be assumed to be 12 inches, and height may be assumed to be 6 inches. When sandbag structures are built in a pyramidal shape, the base of the structure may be assumed to be about 3 times its height.

Number of Sandbags Required for 100 LF of Berm	
Height of Berm (feet)	**Number of Bags**
1	334
2	934
3	1800
4	2934
5	4334
6	6000

Table 10EP-2
Estimated Number of Sandbags required for a 100-Foot Berm
(Based on filled sand bag dimensions of 1.5’x1.0’x0.5’)

Suspended pipe diversions shall be paid for under the following item numbers:

- 209-09.01, Sandbags, per Bag
- 209-20.03, Polyethylene Sheeting (6 mil minimum), per SY
- 621-03.02 thru 621-03.11, 18” to 72” Temporary Drainage Pipe, per LF
- 709-05.06, Machined Rip-Rap (Class A-1), per Ton
- 709-05.08, Machined Rip-Rap (Class B), per Ton
- 709-05.09, Machined Rip-Rap (Class C), per Ton

10.08.1.11.5 EXAMPLE APPLICATION

Given: An existing 10-foot by 6-foot box culvert in Overton County (CN=75) is to be lengthened by 20 feet on the downstream side to accommodate a proposed roadway widening. The natural channel cross section is trapezoidal, with an 8-foot bottom width, 1.5H:1V side slopes and a height of 3.5 feet. The drainage area at the site is 120 acres with a time of concentration of 1.5 hr and the stream slope is 2.0%. The designer has determined that a suspended pipe diversion may be used at the site.

Find: Design the proposed suspended pipe diversion and compute the required quantities.

Solution:

Step 1: Determine the design flow rate and temporary drainage pipe size: The design flow rate should be based on the 2-Year, 24-hour storm. Since the drainage area at this site is greater than 100 acres, the TR-55 Graphical Peak Discharge Method will be used. The design flow rate is computed as follows:

- For a 2-Year, 24 Hour storm the Rainfall, P = 3.50" (Table 4A-5, TDOT Drainage Manual)
- Initial abstraction, I_a = 0.667" (Table 4-1, Technical Release 55)
- Compute I_a/P

$$\frac{I_a}{P} = \frac{0.667}{3.50} = 0.191$$

- Unit Peak Discharge, q_u = 250 csm/in (Exhibit 4-II, Technical Release 55)
- Runoff, Q

$$S = \frac{1000}{CN} - 10 = \frac{1000}{75} - 10 = 3.333$$ (Equation 2-4, Technical Release 55)

$$Q = \frac{(P-0.2S)^2}{(P+0.8S)} = \frac{(3.50-0.2(3.33))^2}{(3.50+0.8(3.33))} = 1.303"$$ (Equation 2-3, TR 55)

- Pond and Swamp Adjustment Factor, F_p = 1.0 (Table 4-2, Technical Release 55)
- Peak discharge, q_p

$$q_p = q_u A_m Q F_p = (250)(0.1875)(1.303)(1.0) = 61.1$$ cfs (Equation 4-1, TR 55)

Based on the table "Temporary Diversion Culvert Selection" on Standard Drawing EC-STR-32, and a stream slope at the site of 2.0%, a 42-inch diameter pipe is selected for the temporary diversion pipe. Since the existing box culvert has a span of 10 feet, there will be about 3 feet of work room on either side of the temporary drainage pipe, and this is deemed to be adequate.

Step 2: Determine quantities for the proposed diversion pipe:

<u>Item number 621-03.06, 42-inch Temporary Drainage Pipe, per LF</u>

The proposed temporary drainage pipe must be sufficiently long to accommodate the proposed culvert extension as well as the lengths of the sandbag structures at both ends. In addition, additional work room is needed at both ends of the extension. When a sandbag structure is set up in a pyramidal shape, it may be assumed that the length of the base will be three times the height of the structure. Since the height of the box culvert is 6 feet, the plug at the upstream end of the pipe will be 75% of that height, or 4.5 feet. Three times this height is 13.5 feet, which is rounded to 14 feet. The berm at the downstream end of the structure will be approximately 0.5 feet lower than the plug to allow for an emergency overflow. Thus, it will have a height of 4 feet and a base length of 12 feet. It is judged that additional lengths of 5 feet at the upstream end of the pipe and 10 feet at the downstream end will provide adequate work room for the box culvert extension. Thus, the total required length of pipe will be:

$$Pipe\ Length = Plug\ Length + Berm\ Length + Extension\ Length + Workroom =$$
$$14 + 12 + 20 + 5 + 10 = 61 \text{ feet}$$

It is assumed that the 42-inch corrugated metal pipe for this extension will be available in 12-foot long sticks. Thus, the result above is rounded to 60 feet for the final quantity.

<u>Item number 209-09.01, Sandbags, per Bag</u>

The quantity for sandbags will be computed in three parts: the bags required for the upstream plug, for the pipe supports and for the downstream berm. The quantity of bags in the berm, in turn, will be computed by examining the quantity of bags in the channel of the stream separately from the quantity of bags on the overbanks.

As stated above, the downstream channel has a bottom width of 8 feet, 1.5H:1V side slopes, and a height of 3.5 feet. This results in a top width of 18.5 feet for the channel. The height of the berm will be 4.0 feet for a distance of 10 feet in order to form the emergency spillway, and the remainder of the berm will be 4.5 feet high. The berm will be approximately 2 feet wide (in the direction of stream flow) at the top and 12 feet wide at the bottom. Although the shape of the berm within the channel is somewhat complicated, its average length in the direction of stream flow may be found to be 7 feet; its average width may be found to be 14.4 feet and its average height may be found to be 4.2 feet. Thus, the total volume of the berm in the stream channel may be computed as:

$$Volume = Height \times Wdith \times Length = 4.2 \times 14.4 \times 7 = 423.4 \text{ CF}$$

To compute the quantity of sandbags required for this part of the berm, it is necessary to subtract the volume occupied by the temporary pipe. This may be computed as the average length of the berm in the direction of stream flow times the end area of the pipe. Thus:

$$Volume_{Pipe} = (7)\left(\pi \frac{3.5^2}{4}\right) = 67.3 \text{ CF}$$

The net volume of the sandbags in the stream channel may then be computed as:

$$Volume_{Sandbags} = Volume - Volume_{Pipe} = 423.4 - 67.3 = 356.1 \text{ CF} \approx 356 \text{ CF}$$

Since the volume of each sandbag is approximately 0.75 cubic foot, 475 sandbags will be required for this portion of the berm.

Based on inspection of the project site, it is determined that the proposed berm should extend a distance of 10 feet on either side of the channel. To tie the berm into high ground, it will be necessary to turn it towards the road to tie into the roadway embankment. This will require an additional length of 30 feet on either side of the stream, for a total length of 80 feet. Since the berm will be 4.5 feet above the flow line of the channel and the channel itself has a height of 3.5 feet, the berm will be 1 foot high on the overbanks. From Table 10EP-2, 334 bags would be required to construct 100 feet of berm at this height. Thus, the number of bags required on the overbanks may be computed as:

$$Number\ of\ Bags = \frac{334\ Bags}{100\ feet} \times 80\ \ feet \approx 267\ \text{Bags}$$

Combining the number of bags required for the channel and overbanks yields a total of 742 bags required to construct the berm.

As stated above, the sandbag plug at the upstream end of the temporary pipe will have a base length (in the direction of stream flow) of 14 feet. Its length at the top is assumed to be about 2 feet so that the average length will be 8 feet. As also stated above, its height will be 4.5 feet. Its width will be equal to the span of the box culvert, or 10 feet. Thus, the total volume of the plug may be computed as:

$$Volume = 8 \times 4.5 \times 10 = 360\ \text{CF}$$

As with the berm, to compute the quantity of sandbags required for the plug, it is necessary to subtract the volume occupied by the temporary pipe. Since the average length in the direction of flow is 8 feet, this may be computed as:

$$Volume_{Pipe} = (8)\left(\pi \frac{3.5^2}{4}\right) = 77.0\ \text{CF}$$

The net volume of the sandbags in the plug may then be computed as:

$$Volume_{Sandbags} = Volume - Volume_{Pipe} = 360.0 - 77.0 = 283\ \text{CF}$$

Since the volume of each sandbag is approximately 0.75 cubic foot, 377 sandbags will be required for the plug.

The last part of the computation for the sandbag quantity is to determine the number of bags needed to form the pipe supports. The first step of this, in turn, is to determine the number of supports needed. It is assumed that the pipe used to the construct the diversion will have a metal wall thickness of 0.64 inches. From the table “Maximum Span for Pipe Supports” on the standard drawing, the pipe supports should be no further apart than 14 feet. Since the individual sticks of pipe are 12 feet long, it will be adequate to support the pipe only at the joints. Thus, 4 supports will be required.

Since the inside diameter of the pipe will be 3.5 feet, the pipe will be supported on one layer of sandbags, or about 6 inches above the bottom of the culvert. This way, the outside crown of the pipe will be approximately equal to the top of the sandbag plug. To provide sufficient support on both sides of the joints, the sandbags will be placed with the long dimension in line with the direction of flow. Each support will consist of 7 bags laid out across the bottom of the culvert. This will provide sufficient width for a stack of 3 bags on either side of the pipe to prevent rolling. Thus, 13 bags will be required for each support, for a total of 52 bags.

The total number of bags for all of the sandbag structures may then be computed as:

$$Total\ Bags = 742 + 377 + 52 = 1171 \text{ Bags}$$

To provide for variations which may occur in the field, this number is rounded up to the final quantity of 1200 bags.

Item number 209-20.03, Polyethylene Sheeting (6 mil minimum), per SY:

This liner will be required both in the sandbag plug at the upstream end of the temporary pipe and in the channel portion of the sandbag berm downstream of the culvert. Thus, the quantity for this item will be calculated in two parts.

The first part is the quantity of sheeting in the plug at the upstream end of the temporary pipe. Based on cross section "A-A" on the standard drawing, it may be assumed that the liner will be placed at about a 1H:1V slope. Thus, the length through the plug may be computed as:

$$Length = \sqrt{4.5^2 + 4.5^2} = 6.4 \text{ feet}$$

To improve the seal at the bottom of the liner and properly anchor it at the top, allow 18 inches of extra length at each end of the liner. Thus, the total dimension in the vertical dimension is 9.4 feet, which may be rounded to 10 feet.

The liner will be placed into the plug in two parts, in order to fit it around the temporary pipe. Since the required overlap is 18 inches, the width of the liner will be equal to half of the span of the box culvert plus the overlap, or 6.5 feet. Thus, the total width required for both pieces will be 13 feet. The quantity for this portion of the sheeting may then be computed as:

$$Area = 10 \times 13 = 130 \text{ SF = 14.4 SY}$$

The quantity of sheeting in the downstream plug can be calculated in a matter similar to the method used for the upstream plug. The main difference is that the channel has a trapezoidal shape instead of a rectangular shape. The sheeting will be place into the berm up to the level of the spillway. Given the 8-foot bottom width and 1.5H:1V side slopes discussed above, the top width at a depth of 4 feet would be 20 feet, and the average width would be:

$$Average\,Width = \frac{8 + 20}{2} = 14.0 \text{ feet}$$

Since the liner will also be installed in the berm at approximately a 1H:1V slope, its vertical length may be computed as:

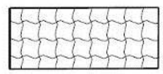
$$Length = \sqrt{4.0^2 + 4.0^2} = 5.7 \text{ feet}$$

Adding 18 inches of additional fabric at the top and bottom of the berm yields a length of 8.7 feet, which is rounded to 9 feet. Since the temporary pipe will protrude through the berm, it will again be necessary to install the liner in two parts. Since the overlap will be 18 inches, the total average width for both parts of the liner will be 17 feet. Thus, the area may be computed as:

$$Area = 9 \times 17 = 153 \text{ SF} = 17.0 \text{ SY}$$

Adding the areas of the two liners together yields a final quantity of 31.4 SY.

10.08.1.12 EROSION CONTROL BLANKET (EC-STR-34)



EROSION CONTROL BANKET

Erosion Control Blanket
Location: SR 840, Williamson County, TN (2004)

10.08.1.12.1 DEFINITION AND PURPOSE

Erosion control blankets are manufactured sheets of mulch materials (e.g., straw, coir, wood fibers, curled wood, etc.) that are bound into netting composed of either photodegradable synthetic or natural materials. They are usually delivered to a construction site in rolls which are then installed as a protective covering on a prepared planting area of a slope. The various types of erosion control blanket are described in detail in Section 5.04.7.

Erosion control blankets are intended to be used as an immediate mulch cover for disturbed slopes that have been temporarily or permanently seeded. The blanket functions to provide protection from erosion due to direct rainfall impact and to provide cover for young vegetation by helping to maintain optimal moisture and temperature conditions.

10.08.1.12.2 APPROPRIATE APPLICATIONS

Erosion control blankets can be highly effective as erosion control measures when properly installed on either cut or fill slopes. They should be installed as soon as possible on disturbed areas where temporary or permanent seeding has been placed. This is especially important on steep slopes (greater than 3H:1V) where the probability of erosion is high and quick vegetation establishment is imperative. They are also useful at locations where high winds could act to displace standard mulch materials.

Further, erosion control blankets may be used as a liner for constructed channels where the anticipated maximum shear stress is low. Refer to EC-STR-36 for channel installation details.

10.08.1.12.3 LIMITATIONS

Utilizing erosion control blankets can represent somewhat increased costs for both materials and installation labor as compared to straw mulching.

Erosion control blankets should not be used in a stream where base flow exists year-round.

10.08.1.12.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is not required. However, for each location erosion control blankets are used the type of blanket should be indicated in the EPSC plans.

As described in Section 5.04.7, erosion control blankets are classified into four types. Refer to the TDOT Qualified Products List and TDOT Standard Specification 918.28 for additional information.

The use of erosion control blankets on cut or fill slopes may be considered for the following conditions:

A. In flat or rolling terrain, on 2H:1V or 3H:1V fill slopes and/or 2H:1V or 3H:1V cut slopes (in soils) that are 20 feet or greater in height;

B. In mountainous or hilly terrain, 2H:1V or 3H:1V fill slopes and/or 2H:1V or 3H:1V cut slopes (in soils) that are 30 feet or greater in height;

C. On slopes that have heights less than A or B but are built of highly erodible soils such as sandy soils in West Tennessee;

D. On slopes where a roadway is passing through a small urban or residential area and sod is not specified. Slopes on urban projects with curb and gutter should be sodded;

E. On slopes running adjacent to a stream or adjacent to a large ditch or channel that drains directly into Exceptional Tennessee Waters or sediment-impaired stream near the roadway construction;

F. On bridge and approach projects when crossing Exceptional Tennessee Waters or sediment-impaired waters;

G. As temporary slope protection on the front and side slopes of bridge abutments, when sod is not required;

H. On slopes where the installation of silt fence, sediment tubes, and/ or filter socks would be considered unduly difficult;

I. At points of stormwater runoff concentration from pavement to slope, such as the low side of a superelevated section, the low areas of sag vertical curves, etc.;

J. At point of stormwater runoff concentration where off-site runoff threatens stability of cut slopes;

K. At all locations specified by the Soils and Geology Sections of the Materials and Test Division

L. At locations requested during project field reviews

The erosion control blanket type for a graded area should be selected as follows:

- Type I blankets should be used on continuous slopes that are 3H:1V or flatter and up to 20 feet in height.

- Type II blankets should be used on continuous slopes that are 3H:1V or flatter and greater than 20 feet in height and on continuous 2H:1V slopes that are up to 80 feet in height.

- Type III blankets should be used on continuous 2H:1V slopes that are over 80 feet in height.

- Type IV blankets should be used on slopes only when specified by the Soils and Geology Section of the Materials and Tests Division.

The guidance provided above should be sufficient for the selection of an erosion control blanket type. However, where a more detailed analysis is desired, the Revised Universal Soil Loss Equation may be utilized, as described in Section 10.03. The expected soil loss from a slope protected with erosion control blanket can be compared with the loss from a bare slope by adjusting the cover-management factor, C. Manufacturers of erosion control blankets supply typical C factors for each type of blanket. These values are based on field testing of the blankets under varied conditions.

On sites with flat slopes or short slope lengths, it may be possible to substitute mulch control netting or open weave textiles for erosion control blanket, based on economic considerations. Where this is done, the seeding quantity should be computed as Item No. 801-01, Seeding (with Mulch) per unit for the graded area.

The selection of an erosion control blanket for a stream channel lining will be based on whether the seeding will be temporary or permanent. For permanent seeding, the designer should consider the shear stress imposed on the fully vegetated channel at the ditch design flow rate (that is, the 10-year or the 50-year event). As described in Chapter 5, a seeded or sodded ditch lining will resist erosion only when the maximum shear is 2.0 lb/ft^2 or less. As a result, the ultimate strength of the lining will be limited even where the erosion control blanket is capable of resisting higher shear stresses. Thus, for permanent seeding in a channel, an erosion control blanket should be specified only where the maximum shear at the design discharge is 2.0 lb/ft^2 or less. Where it is greater than this amount, a turf reinforcement mat may be specified as described in section 10.08.1.12. Procedures for determining the shear stress in a grassed waterway are provided in Section 5.06.

Where temporary seeding is being applied to a channel, it is usually not necessary to consider the ultimate shear strength of the grassed lining. In this case, the type of erosion control blanket may be selected based on the maximum shear imposed by the 2-year peak discharge on the un-vegetated blanket. However, at sites which drain to Exceptional Tennessee Waters or sediment-impaired streams, the maximum shear imposed by the 5-year peak discharge should be considered. Procedures for determining this shear stress are also provided in Section 5.06 and permissible shear stresses are provided in Table 5A-7.

In addition to the above criteria, the designer should consider the design life of the erosion control blanket. The designer should ensure that it is possible for the permanent vegetation to become well established before the degradable portions of the blanket have degraded to the point that their resistance to erosion is significantly reduced. Type I and II blankets should be considered to have a design life of 12 months. Type III and Type IV blankets have design lives of 24 and 36 months, respectively.

Proper installation of blankets is critical to ensure that the intended results are achieved. The contractor must install the blanket on a slope that is cleared of large rocks and debris to insure that close contact with the soil is maintained throughout the run length of the blanket. Experience has shown that good contact is necessary to encourage the germination and growth of the grass seed.

When erosion control blankets are specified, it will not be necessary to include mulch with the seeding item. The designer in this case should use Item No. 801-02, Seeding (without Mulch) per unit, for the seeding item.

When erosion control blankets are utilized in a ditch that is adjacent to seeded and mulched slopes, the seeding quantity for the ditch area should be still be Item No. 801-01, Seeding (with Mulch) per unit.

When erosion control blankets are used with crown vetch mixture, it will not be necessary to use mulch. Thus, the seeding item should be Item No. 801-02.01, Crown Vetch Mixture (without Mulch) per unit.

Erosion control blankets for slope installations shall be paid for under the following item numbers:

- 801-02, Seeding (without mulch), per unit
- 801-02.01, Crown Vetch Mixture (without mulch), per unit
- 801-02.08, Temporary Seeding (without mulch), per unit
- 805-12.01, Erosion Control Blanket (Type I), per SY
- 805-12.02, Erosion Control Blanket (Type II), per SY
- 805-12.03, Erosion Control Blanket (Type III), per SY
- 805-12.04, Erosion Control Blanket (Type IV), per SY

10.08.1.12.5 EXAMPLE APPLICATION

Given: A 450-foot section of a roadway relocation project in Knox County will require a large cut in a hill adjacent to the site. As currently proposed, the slope will be 85 feet high and at a 2H:1V grade. Due to the length and grade of this slope, there is concern that it be stabilized against erosion as quickly as possible. A roadway side ditch is to be constructed at the toe of the slope, and this ditch will have a 2H:1V back slope, a 4-foot bottom width and a 6H:1V fore-slope. In addition, the ditch will have a longitudinal slope of 0.5%. A 20-foot wide clear zone at a 6H:1V grade will be provided between the roadway shoulder and the side ditch. Runoff from the site will be conveyed through the proposed roadway side ditch to a stream which is listed as Exceptional Tennessee Waters.

Find: Select erosion control blankets for the cut slope, roadway side ditch and clear zone and compute the required quantities for erosion control blanket and seeding.

Solution: The portion of the cross section being considered in this example application presents three unique situations. Thus, erosion control blanket will be considered individually for each situation.

Step 1: Select an erosion control blanket for the large cut slope: Based on the guidance provided in the Planning and Design Criteria, a Type III erosion control blanket should be selected for the cut slope. Given the sensitive nature of the waterway receiving the runoff from the site, it is decided to take the additional step of evaluating the potential for erosion from the cut slope using the Revised Universal Soil Loss Equation (RUSLE).

As described in Section 10.03, the RUSLE may be written as:

$$A = (R)(K)(LS)(C)(P)$$

Where:

A = average annual soil loss, tons per acre per year
R = rainfall-runoff erosivity factor, hundreds of foot-tons (force)-inch per acre-hour-year
K = soil erodibility factor, ton-acre-hour per hundreds of acre-foot-ton (force)-inch
LS = topographic factor, dimensionless
L = slope length factor, dimensionless
S = slope steepness factor, dimensionless
C = cover-management factor, dimensionless
P = support practice factor, dimensionless

For this example, the RUSLE parameters are determined as follows:

- Based on Table 10A-1 the value of R for Knox County is 180;
- Since the soils on the slope appear to be silty clay loam, a value of 0.32 is selected from Table 10-2;
- Since the height of the slope is 85 feet, the overall slope length may be computed as:

$$L = \sqrt{85^2 + (2 \times 85)^2} = 190.1 \text{ feet}$$

- Interpolating from Table 10A-2 at a slope of 50% yields an LS value of 15.48;
- In order to provide a basis for comparison, the RUSLE computation will be done first for bare soil, which corresponds to a value of 1.0 for C, as indicated by Table 10-3;
- Finally, a value of 1.3 for P is selected from Table 10-4, based on the worst-case assumption of a compacted smooth surface scraped with bulldozer up and down slope.

Given these parameters, the average annual soil loss for a bare slope is computed as:

$$A = (180)(0.32)(15.48)(1.0)(1.3) = 1159 \text{ tons/ac/year}$$

The total surface area of the cut slope is computed as:

$$Area = 450 \ feet \times 190.1 \ feet \times \frac{1\,acre}{43{,}560 \ ft^2} = 1.964 \text{ acres}$$

Thus, the average annual soil loss from the cut slope with bare soil would be 2276 tons/year.

In order to determine the effect of covering the slope with an erosion control blanket, an appropriate C-value of 0.35 for a typical Type III blanket, is obtained from Table 5A-7 in this manual. Since the remaining factors in the RUSLE are unchanged when the cover-management factor is adjusted, the soil erosion rate for a slope covered with the Type III blanket may be computed simply by multiplying the ratio between the two C-values. Since the C-value for bare soil was 1.0, the soil loss rate with the blanket (in an un-vegetated condition) would be 797 tons/year.

Given the classification of the receiving stream, the soil loss rate, even with erosion control blanket is considered to be unacceptable. Further, there is some concern for the long-term maintenance of a 2H:1V slope of this size. Thus, the designer decides to contact the Geotechnical Section to discuss utilizing a Type IV erosion control blanket or of using stair-step grading, as described in Section10.03. However, the use of either of these options is beyond the scope of this example application. Therefore, this discussion will continue under the assumption that a Type III blanket may be utilized on the cut slope.

Step 2: Select an erosion control blanket for the roadway side ditch: The roadway side ditch is not expected to be reworked during the course of the project. Therefore, it is assumed that this area will be seeded once with permanent seeding. As described in the Planning and Design Criteria, the shear imposed by the ditch design discharge must be checked so that a permanent liner can be selected for this area. Thus, it is first necessary to compute the ditch design flow rate using the Rational Method, as described in Section 4.04. In order to provide a conservative analysis, the Runoff Coefficient, C, is assumed to be 0.8, which reflects disturbed, bare soils. In addition, it is assumed that the time of concentration will be 5 minutes. Based on the Knoxville IDF curves provided in Table 4A-7, the 10-year, 5-minute rainfall intensity is 6.1 in/hr. The drainage area includes the 20-foot width of the clear zone, a width of approximately 12 feet for the roadway side ditch and a slope length of 190.1 feet for the cut slope. Adding these widths and multiplying by the project length of 450 feet yields a drainage area of 2.294 acres. Thus, the 10-year ditch design flow rate is computed as:

$$Q_{10} = (0.8)(6.1)(2.294) = 11.19 \text{ cfs}$$

The methods provided in Section 5.06 for determining the flow depth in a grassed ditch are utilized to determine a flow depth of 1.33 feet for the 10-year peak flow rate. The shear stress imposed by this flow is computed from Equation 5-10 as:

$$\tau_{max} = \gamma d S = (62.4)(1.33)(0.005) = 0.41 \text{ lb/ft}^2$$

Since the shear imposed by the peak ditch design flow rate is less than 2.0 lb/ft^2, it will be possible to use erosion control blanket over the permanent seeding. Computing the depth of flow and shear for the 5-year event results in a shear stress 0.22 lf/ft^2. Based on Table 5A-7, it would be possible to use a Type I blanket on the side ditch. However, the cut slope immediately adjacent to the ditch must utilize a Type III blanket, due to the forces exerted by the runoff generated on that slope. Since these forces will also be exerted on the ditch as runoff from the slope enters it, a Type III liner is selected for the roadside ditch as well.

Step 3: Select an erosion control blanket for the clear zone: Since the clear zone is 20 feet wide with a 6H:1V grade, it is judged that sufficient erosion prevention can be achieved by the use of a Type I erosion control blanket.

Step 4: Compute quantities for erosion control blanket and seeding: The pay items for this example application can be computed based on the surface areas of each of the three cross section segments discussed above. The surface area of the cut slope was determined above to be 85,845 ft^2 (190.1 feet multiplied by 450 feet). Since the ditch area is assumed to be about 1.5 feet deep, the width of the foreslope will be 9 feet, and the width of the back slope will be 3 feet and the bottom width will be 4 feet, for a total of 16 feet. This results in a surface area of 7200 ft^2 across the 450-foot width of the project. The surface area of the 20-foot wide clear zone will be 9000 ft^2.

The pay items for site include:

Item Number 805-12.03, Erosion Control Blanket (Type III), per SY

Only two areas within the project site will receive erosion control blanket: the cut slope and the roadway side ditch. The combined surface area of these two sections is 93,045 ft^2, which is divided by 9 SY/ft^2 to yield the final quantity of 10,338 SY.

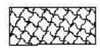
Item Number 801-01, Seeding (with Mulch), per Unit

At this site, only the clear zone is to receive seeding with mulch. However, based on the Planning and Design Criteria provided above, when a ditch to be located adjacent to an area which is to be seeded and mulched, the seeding item for the ditch area should still be mulched seeding even through erosion control blanket is to be used. Thus, the quantity for this item will be computed based on the combined area of the clear zone and the roadway side ditch, or 16,200 ft^2. Since there are 1000 ft^2 per unit, the final quantity for this item will be 16.2 units.

Item Number 801-02, Seeding (without Mulch), per Unit

Since the area of the roadway side ditch is included with the quantity for mulched seeding, the only area to be considered for this item is the surface area of the cut slope, which is 85,845 ft^2. Since there are 1000 ft^2 per unit, the final quantity for this item will be 85.8 units.

10.08.1.13 TURF REINFORCED MATS (EC-STR-36)



TURF REINFORCEMENT MAT

Turf Reinforcement Mat
Location: SR 840, Williamson County, TN (2004)

10.08.1.13.1 DEFINITION AND PURPOSE

Turf reinforcement mats (TRM's) are used to permanently stabilize ditches and swales. Unlike temporary measures such as erosion control blankets, these measures contain elements which resist decomposition and remain in place in order to supplement the erosion resistance offered by the seeded vegetation. Thus, TRM's provide long-term stabilization for grassed ditches and swales where the shear forces exerted by the design flow are in excess of stability limits of vegetation alone.

Although these measures are primarily intended to form a permanent lining, they are flexible and thus capable of conforming to changes in channel shape which may occur due to erosion or settlement of the soil. In addition, they are generally less expensive than rigid linings. Additional information on TRM's can be found in Section 5.04.7.

10.08.1.13.2 APPROPRIATE APPLICATIONS

This measure is primarily intended to allow vegetation to be used as a ditch liner at locations where the shear force imposed by the design discharge exceeds 2.0 lb/ft^2, which is the maximum permissible shear for a lining composed of sod or grasses as discussed in Chapter 5.

10.08.1.13.3 LIMITATIONS

Although TRM's can provide very high shear resistance once vegetation has been fully established, their shear strength in an unvegetated state is much less, usually no more than 3.0 lb/ft^2. Thus, its use as a temporary lining material is limited.

Because of the relatively greater density of TRM's, they can require longer grow-in periods for the establishment of vegetation as compared to erosion control blankets.

10.08.1.13.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is required in that the hydrologic and hydraulic analysis of the ditch is necessary in order to determine the anticipated maximum shear stresses that will be imposed along the face of the ditch. In addition, the designer should refer to Section 5.04.7.2 for detailed information on the selection of a liner type. At each location turf reinforcement mats are used the class of the TRM should be indicated in the EPSC plans.

Although not strictly a design issue, it is important to note that proper installation of a TRM is crucial to its overall success. Care must be taken to ensure that the material is properly secured by the use of check slots and stakes, as detailed on the standard drawing. The matting must also be installed on a surface that is cleared of large rocks and debris in order to ensure that close contact with the soil is maintained throughout the length of the lining. This helps to provide optimal conditions for the germination and development of the grass. Finally, TRM's should be placed immediately after seeding is complete.

As with any vegetated lining, TRM's should not be used where standing water or perennial flows would tend to drown the seeded grasses. Where such conditions exist, the bottom of the ditch may be lined with riprap up to the depth of the standing water and TRM's installed on the sides of the ditch above that level. However, this approach should not be used in a stream or other type of natural waterway.

Because a TRM is considered a permanent lining, the selection of TRM class should be based on the flow rate used to design the ditch. That is, if the design frequency for the drainage system, as prescribed in Table 4-1 is 50 years, the selection of the TRM class should be based on the 50-year event as well. Because the TRM will not contribute to the hydraulic roughness of the channel once the vegetative cover has been fully established, the depth of flow and shear force for a given flow rate should be computed assuming a grassed lining, using procedures provided in Section 5.06. Once the shear force at the ditch design flow rate has been computed, it is possible to select a class of TRM from Table 5A-7.

As noted above, the shear strength of an unvegetated TRM is 3.0 lb/ft^2, which is usually significantly less than the strength of the lining once the vegetation has been fully established. Thus, it is important to check the stability of the unvegetated lining. Since it will usually take 1 to 2 growing seasons for the vegetation to establish, the unvegetated shear strength should be checked for the peak discharge generated by the storm event specified in Section 10.05.1. Where the computed shear exceeds the permissible value for the unvegetated lining, the ditch should be provided with a riprap lining up to the depth of flow in the specified storm event. However, this approach should not be used in a stream or other type of natural waterway.

Once the class of TRM has been selected, the lining should be provided with sufficient freeboard above the flow depth computed for the ditch design discharge. For a straight channel alignment with a moderate flow velocity, the freeboard should be equal to half of the computed flow depth, or 2 feet, whichever is less.

TRM manufacturers typically test their products to determine the maximum shear forces that the matting can withstand in the field under unvegetated and vegetated conditions. Usually, these tests are based on flow durations of 30 minutes. If conditions exist which would cause flows to occur for significantly longer periods of time, the designer may consider specifying the next heavier class of TRM.

When TRM's are specified, it will not be necessary to include mulch with the seeding item. The designer in this case should use Item No. 801-02, Seeding (Without Mulch), per unit or Item No. 801-02.01, Crown Vetch Mixture (Without Mulch), per unit for the seeding item.

Turf Reinforcement Mats shall be paid for under the following item numbers:

- 801-02, Seeding (Without Mulch), per Unit
- 801-02.01, Crown Vetch Mixture (Without Mulch), per Unit
- 801-02.08, Temporary Seeding (Without Mulch), per Unit
- 805-01.01, Turf Reinforcement Mat (Class I), per SY
- 805-01.02, Turf Reinforcement Mat (Class II), per SY
- 805-01.03, Turf Reinforcement Mat (Class III), per SY

10.08.1.13.5 EXAMPLE APPLICATION

Given: A proposed side ditch for a freeway will extend a distance of 500 feet at a slope of 3.0%. The ditch cross section is to consist of a 6H:1V foreslope, a 4-foot bottom width and a 4H:1V backslope. Based on analysis by the Rational Method, it has been determined that the 50-year peak flow rate in the ditch will be 37.4 cfs, and the 2-year peak flow rate will be 24.5 cfs. For aesthetic reasons, a vegetated liner is required for this location.

Find: Determine the type of liner which would be required for this ditch and compute the associated quantities.

Solution:

Step 1: Determine the depth of flow in the ditch for the 50-year discharge: Since the permanent liner in this ditch is to be grass, the depth of flow at the 50-year peak discharge must be determined using the procedure outlined in Section 5.06.1. As described in Chapter 5, the hydraulic roughness of a grassed channel lining will vary as the depth changes. Thus, it is necessary to determine the depth by a trial-and-error process. For a depth of 1.19 feet, the wetted perimeter of the flow, WP, may be computed as:

$$WP = \sqrt{1.19^2 + (6 \times 1.19)^2} + 4.0 + \sqrt{1.19^2 + (4 \times 1.19)^2} = 16.15 \text{ feet}$$

Similarly, the cross sectional area of the flow, A, may be computed as:

$$A = 0.5(1.19^2)(6) + 4(1.19) + 0.5(1.19^2)(4) = 11.84 \text{ ft}^2$$

The hydraulic radius, R_h, is then computed as:

$$R_h = \frac{A}{WP} = \frac{11.84}{16.15} = 0.733 \text{ feet}$$

The hydraulic roughness of the channel is determined by computing a Manning's n-value using Equation 5-14. As stated in Chapter 5, since the specific species of grass and long-term maintenance practices are not possible to determine, it is assumed that the grass will be in vegetal retardance class "C" and Table 5-1 is used to determine a value of 30.2 for the parameter C_{rf}. Thus, Manning's n is computed as:

$$n = \frac{R^{1/6}}{C_{rf} + 19.97\,log\left(R^{1.4}\,S^{0.4}\right)} = \frac{0.733^{1/6}}{30.2 + 19.97\,log\left(0.733^{1.4} \times 0.03^{0.4}\right)} = 0.067$$

With this information, a flow rate corresponding to a depth of 1.19 feet can be computed using Manning's Equation:

$$Q = \frac{1.486}{n} AR^{0.67} S^{0.5} = \frac{1.486}{0.067}(11.84)(0.733)^{0.67}(0.03)^{0.5} = 37.0 \text{ cfs}$$

Since the computed discharge value is sufficiently close to the actual 50-year discharge, the trial depth of 1.19 feet is accepted as the depth for this flow.

Step 2: Determine the maximum shear stress at the 50-year flow and select the lining type: Since the proposed ditch is to be on a straight alignment, the shear at the 50-year flow rate may be computed from Equation 5-10 as:

$$\tau_{max} = \gamma d S = 62.4(1.19)(0.03) = 2.23 \text{ lb/ft}^2$$

As discussed in Chapter 5, the maximum permissible shear stress on a sodded or grassed channel lining is 2.0 lb/ft^2. Since the computed shear exceeds this value, it will be necessary to supplement the vegetated lining with a turf reinforcement mat. Based on Table 5A-7, a Class II TRM is selected for this site because it can withstand shear stresses up to 5.0 lb/ft^2.

Step 3: Determine the maximum shear stress on the unvegetated TRM for the 2-year discharge: Since the shear strength of the unvegetated TRM is usually less than the strength of the fully-developed lining, it would normally be necessary to compute the depth of flow for the 2-year discharge in order to ensure that the shear stress would be no more than 3.0 lb/ft^2. In this situation, the computed shear for the 50-year event is already less than 3.0 lb.ft^2, and it may be safely assumed that the shear for the 2-year event would be acceptable. However, for illustrative purposes, the computations will be shown for this example.

As discussed in Chapter 5, the hydraulic roughness of an unvegetated TRM will vary for depths between 0.5 and 2.0 feet. Thus, the depth of flow for the 2-year discharge must be determined by a trial and error process. For a depth of 0.73 feet, the wetted perimeter and cross sectional flow area were computed as described above and found to be 11.45 feet and 5.58 ft^2, respectively. Dividing the flow area by the wetted perimeter will result in a hydraulic radius of 0.49 feet.

As shown in Table 5A-6, the Manning's n-value for an unvegetated TRM is 0.04 for a depth of 0.5 feet and 0.015 for a depth of 2.0 feet. Using linear interpolation, an n-value of 0.036 is determined for the trial depth of 0.73 feet. Using Manning's Equation as shown above, a discharge of 24.7 cfs is computed for the trial depth. Since the computed flow rate is sufficiently close to the actual flow rate of 24.5 cfs, this depth is accepted as the actual depth of flow for the

2-year event. The shear stress for this flow rate is then determined to be 1.37 lb/ft^2. Since this is less than 3.0 lb/ft^2, the TRM will remain stable in the 2-year event, and it will not be necessary to line the channel bottom with riprap.

Step 4: Determine the height of the lining above the channel bottom: As described in the Planning and Design Criteria, the channel lining should be provided with a freeboard equal to half of the computed depth for the ditch design discharge. In step 1, it was determined that the depth of flow at the 50-year discharge would be 1.19 feet. Since half of this is 0.60 feet, the total height of the TRM lining above the channel bottom should be 1.79 feet.

Step 5: Compute quantities: The pay items to be considered for this example application are:

<u>Item Number 805-01.02, Turf Reinforcement Mat (Class II), per SY</u>

For a lining height of 1.79 feet, the length of the lining across the channel, L_t, may be computed as:

$$L_t = \sqrt{1.79^2 + (6 \times 1.79)^2} + 4.0 + \sqrt{1.79^2 + (4 \times 1.79)^2} = 22.3 \text{ feet}$$

Considering that turf reinforcement mats are supplied in 4-foot widths, and accounting for the overlap required by the standard drawing, L_t is rounded up to 23 feet. Because the channel is to be 500 feet long, the total surface area (and the final quantity) of the TRM will be:

$$Area = 23 \times 500 = 11{,}500 \text{ ft}^2 = 1278 \text{ SY}$$

<u>Item Number 801-02, Seeding (without Mulch), per Unit</u>

Since the area to be seeded will be equal to the surface area of the TRM, the final quantity for this pay item will be 11.5 units.

10.08.1.14 GABION CHECK DAMS (EC-STR-55 THROUGH 59)

Gabion Check Dams
Reference: Environmental Geological Agency

10.08.1.14.1 DEFINITION AND PURPOSE

This erosion prevention measure consists of a small check dam constructed from gabion baskets placed across a swale, drainage ditch or area of concentrated flow. The gabion baskets are placed in two rows, one on top of the other. The upper row is divided into two parts, one on each side of the channel, so that an open space is provided at the center of the structure to form an overflow weir.

Gabion check dams act to prevent erosion in a ditch by reducing flow velocities. In the same way, they can encourage the settlement of sediments which may be carried by the water. While small amounts of sediment may be collected within or behind the gabions, this measure should not be considered a sediment trapping device.

10.08.1.14.2 APPROPRIATE APPLICATIONS

Gabion check dams may be utilized in small open channels where check dams composed of loose rock (see Section 10.08.1.2) may not be feasible, including:

- temporary or permanent swales or ditches collecting runoff from a watershed that is not stabilized against erosion, where shear forces and velocities are expected to be high
- temporary or permanent swales or ditches in need of protection during establishment of grass linings; or
- other locations where small localized erosion and resulting sedimentation problems may exist

Gabion check dams are intended to be used as an alternative to rock check dams in situations where rock check dams would not be either practical or stable. Gabion check dams may be considered where:

- the drainage area of the ditch exceeds 10 acres, which is the limit for loose rock check dams
- the slope of the ditch exceeds 4%
- site conditions are such that access by the equipment needed to construct a dumped rock check dam is difficult or limited

One of the primary uses of gabion check dams is to act as permanent velocity control structures in very steep ditches. In this setting, the check dams would act as hardened “stair steps” which would allow the water to drop without causing erosion. This would also allow the ditch grade between the structures to be flattened so that flow velocities can be reduced.

10.08.1.14.3 LIMITATIONS

The maximum drainage area for gabion check dam use shall be 35 acres.

The construction of a gabion check dam requires more time and is more costly as compared to other possible measures. The removal of temporary gabions will also result in considerable disruption to the sides of the ditch. In addition to the work needed to remove the gabions, additional excavation will be required to remove the riprap wedges and any coarse aggregate which may have been used to fill the voids between the gabions and the natural ground. Thus, both greater effort and greater cost are required in restoring the area where the check dam was placed.

Gabion check dams should not be placed in a natural stream, or at any other location where the installation of this measure would require an individual Aquatic Resources Alteration Permit from the Tennessee Department of Environment and Conservation or a USACE Section 404 permit.

10.08.1.14.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is not required when used as a temporary measure. However, when gabion check dams are to remain as a permanent feature, formal design is required. Each gabion check dam used should be labeled on the EPSC plans with the following information: as permanent or temporary (or both), the required weir width, the size and length of gabion for the lower row, and the size and length of gabion for the upper row.

Standard Drawing EC-STR-56 provides tables which may be used to select a check dam configuration based on the bottom width and the side slopes of the ditch, as well as the flow rate, as described in the following paragraph.

The table “Gabion Check Dam Weir Lengths and Allowable Flow Rates” on EC-STR-56 specifies the maximum flow rates which may be allowed for a large variety of check dam configurations. In order for the structure to provide adequate erosion prevention during construction, the peak discharge generated by the storm event specified in Section 10.05.1 at the site should be less than or equal to the weir flow value provided on the table. For sites which drain to Exceptional Tennessee Waters or sediment-impaired streams, the weir shall be sized to contain the 5-year/24-hour storm.

The flow rates specified on EC-STR-56 are based on providing adequate erosion prevention during construction before the permanent ditch lining has been established. These flow rates are much lower than the discharges which could be passed over the weir without overtopping the structure. Thus, gabion check dams left in place as permanent structures will be able to accommodate much greater storm events without any modification to the design, provided that the permanent ditch lining has been well-established. Where a gabion check dam is being proposed as a permanent structure, the capacity of the weir should be checked for the drainage design storm frequency as specified in Table 4-1. This check should include two different criteria. First, the depth of flow on the weir should be checked to ensure that the structure will not be overtopped. This can be accomplished by using the broad-crested weir equation (see Section 8.05.7), re-arranged as:

$$H = \left[\frac{Q}{Cw} \right]^{2/3} \qquad \text{(10EP-1)}$$

Where: H = depth of flow on the weir, feet
Q = discharge, ft^3/s
C = broad-crested weir coefficient, (3.0 for this computation), and
w = width of weir crest, feet

The second criterion to be tested is whether the maximum allowable shear on the surface of the gabion basket will be exceeded. Although the water surface would be at the depth, H computed above, as it flows onto the weir, it will pass through critical depth, d_c, as it flows across the downstream side of the weir. Since this is the minimum depth which will occur on the weir, this also represents the point of greatest velocity and shear stress. For a rectangular cross section, critical depth can be computed from:

$$d_c = \left(\frac{Q}{w\sqrt{g}} \right)^{2/3} \qquad \text{(10EP-2)}$$

Where: d_c = critical depth, feet,
Q = flow rate, cfs,
w = width of the weir, feet, and
g = acceleration of gravity, 32.2 ft/sec^2.

The friction slope corresponding to the critical depth, S_c, can then be determined by re-writing Manning's Equation (see Section 5.03) as:

$$S_c = \left[\frac{Q \times n \times (w + 2d_c)^{2/3}}{1.486 \times (w \times d_c)^{5/3}} \right]^2 \qquad \text{(10EP-3)}$$

Where: S_c = friction slope at critical depth, ft/ft,
Q = flow rate, cfs,
n = Manning's n-value (0.069 for the gabion filler stone),
w = weir width, feet, and

d_c = critical depth, feet.

Finally, the shear stress at critical depth, τ_c, may be computed as:

$$\tau_c = \gamma d_c S_c \qquad (10EP-4)$$

Where: γ = specific weight of water, 62.4 lb/ft^3

The gabion basket should remain stable (although some deformation of the wire may occur) for shear stresses up to 5.3 lb/ft^2.

The top of the upper gabion row in a check dam should not be above the top of bank in a defined channel. In general, where an option exists for the height of the lower gabion row, the larger size should be selected. For example, given a design discharge of 13 cfs in a channel with 3H:1V side slopes, the height of the lower gabion row could be either 12 or 18 inches. A lower gabion height of 18 inches should be used, provided that the top of the overall structure will not be above the top of the ditch banks.

The side slopes of the channel should be 2H:1V or flatter.

It should be noted that the stone specified as fill for the gabion baskets has a gradation smaller than that of machined riprap Class A-1. Thus, this material should not be used to form the riprap wedge on the downstream side of the check dam.

Geotextile fabric (Type III) should be placed between the base of the gabion check dam and the prepared surface of the excavation for the structure. This fabric should meet the requirements of the standard specification for geotextiles, AASHTO designation M-288, Erosion Control.

The spacing between gabion check dams should comply with the table "Gabion Check Dam Spacing" on Standard Drawing EC-STR-55 and is based on the longitudinal ground slope of the flow line of the ditch.

In general, gabion check dams should be used where other erosion prevention measures are not feasible, or where economically justified. In particular, the designer should consider the use of turf reinforcement mats (see Section 10.08.1.12) as an alternate to gabions for sites where the ditch grade is 10% or less and where the drainage is 35 acres or less.

Gabion check dams shall be paid for under the following item numbers:

- 209-05, Sediment Removal, per CY
- 709-05.06, Machined Rip-Rap (Class A-1), per Ton
- 709-10.01 thru 709-10.05, Gabions (Description), per CY
- 740-10.03, Geotextile (Type III) (Erosion Control), per SY

When specifying gabion check dams, the cost of excavation to prepare the gabion foundation will be included in the cost of gabions. Thus, a separate item will not be computed for excavation.

10.08.1.14.5 EXAMPLE APPLICATION

Given: A roadway side ditch for a pavement replacement project on a freeway will direct the runoff from approximately 5.0 acres into a proposed swale which will carry flows to a river which runs parallel to the roadway. The roadway is situated at the top of a hill which slopes steeply down to the river, which has been listed as Exceptional Tennessee Waters. The proposed swale will have a planimetric length of 170 feet and will be at a slope of 8.0%. It is proposed to have a 4-foot bottom width with 3H:1V side slopes. The height of this swale, from the flow line to the top of bank will be 4.0 feet. Due to the environmentally sensitive nature of the receiving waters, it is desired to provide a vegetated lining for the swale, if possible. Rational Method computations have determined that the 5-year peak discharge will be 22.2 cfs while the 50-year peak discharge will be 29.2 cfs.

Find: Determine whether gabion check dams will be suitable for this site as permanent velocity control structures. Determine the required gabion check dam dimensions and compute the required quantities.

Solution: Because the slope of the swale is greater than 4%, it is likely that rock check dams will not remain stable at this site. Thus, it is decided to evaluate gabion check dams as permanent velocity control devices.

Step 1: Determine the required gabion check dam configuration: Since this site drains to a designated Exceptional Tennessee Water, the flow rates provided in the table "Gabion Check Dam Weir Lengths and Allowable Flow Rate" on EC-STR-56 will be compared with the 5-year peak flow rate at the site in order to select a suitable gabion check dam configuration. This table contains one row which corresponds to a channel bottom width of 4 feet; and on that row there are five possible configurations which correspond to 3H:1V channel side slopes. However, the allowable flow rates for three of these configurations are less than the 5-year flow rate at the site; thus there are two possible configurations:

- Option 1 consists of a 36-inch lower gabion row, with a 12-inch upper gabion row, a weir width of 16.5 feet and an allowable flow rate of 30.6 cfs, and
- Option 2 consists of a 36-inch lower gabion row, with an 18-inch upper gabion row, a weir width of 12.3 feet and an allowable flow rate of 33.8 cfs.

It is decided to use Option 1 as it will fit within the proposed 4-foot depth of the swale and a 12-inch gabion will presumably be less expensive to construct than an 18-inch gabion.

EC-STR-56 also provides two tables which specify the required lengths of gabion in each row and the lengths of embedment into the sides of the channel for the ends of the two rows of gabions. Based the table for the upper row, the upper row will require a gabion length of 6.0 feet on each side of the structure, as well an upper embedment length of 1.5 feet and a lower embedment length of 4.5 feet. As shown in the other table, the lower row will have a total length of 21 feet, with an upper embedment length of 0.25 feet and a lower embedment length of 8.5 feet.

It is also useful to determine the depth of embedment of the lower gabion row into the channel bottom. As specified on the standard drawing, the downstream face of the lower row should be embedded 3 inches. Since the proposed swale will have a slope of 8.0%, the depth of embedment on the upstream side of the lower gabion row may be computed as:

$$Depth\ of\ \ embedment = 3\ inches + \left(36\ inches \times 0.08\right) = 5.9\ \text{inches}$$

The planimetric length of the riprap wedge should also be determined. The 2H:1V slope of the wedge corresponds to a 50% slope. Since the ditch will be at an 8.0% slope, the difference between these corresponds to a slope of 42%. The height of the upstream end of the riprap wedge will correspond to the height of the lower gabion row, which, accounting for the 3-inch embedment depth, is 33 inches or 2.75 feet. Thus, the length of the wedge will be:

$$Length\ of\ \ wedge = \frac{2.75\ \ feet}{0.42} = 6.5\ \text{feet}$$

Step 2: Check the weir width for the 50-year discharge: Since the gabion check dams are to be left in place as permanent structures, the adequacy of the proposed weir width should be checked for the 50-year peak discharge. As discussed in the Planning and Design Criteria, this involves checking both the depth of flow on the weir as well as the shear stress at critical depth. Using Equation 10EP-1, the depth of flow on the weir, H, may be computed as:

$$H = \left[\frac{Q}{Cw}\right]^{2/3} = \left[\frac{29.2}{3.0 \times 16.5}\right]^{2/3} = 0.70\ \text{feet}$$

Since the computed depth of flow is less than the 1-foot upper gabion height, the proposed weir passes the first check. The second check involves determining the shear stress at critical depth. Equation 10EP-2 is thus used first to determine the critical depth:

$$d_c = \left(\frac{Q}{w\sqrt{g}}\right)^{2/3} = \left(\frac{29.2}{16.5 \times \sqrt{32.2}}\right)^{2/3} = 0.46\ \text{feet}$$

With the critical depth, it is possible to determine the friction slope at that depth from Equation 10EP-3:

$$S_c = \left[\frac{Q \times n \times \left(w + 2d_c\right)^{2/3}}{1.486 \times \left(w \times d_c\right)^{5/3}}\right]^2 = \left[\frac{29.2 \times 0.069 \times \left(16.5 + \{2 \times 0.46\}\right)^{2/3}}{1.486 \times \left(16.5 \times 0.46\right)^{2/3}}\right]^2 = 0.0967\ \text{ft/ft}$$

Finally, the shear stress may be computed from Equation 10EP-4 as:

$$\tau_c = \gamma\, d_c\, S_c = 62.4 \times 0.46 \times 0.0967 = 2.89\ \text{lb/ft}^2$$

Since the computed shear is less than the allowable shear of 5.3 lb/ft^2, the proposed weir passes both tests for the 50-year peak discharge.

Step 3: Determine the check dam spacing: Since the slope of the proposed swale is 8.0%, the check dam spacing may be determined directly from "Gabion Check Dam Spacing Table" on Standard Drawing EC-STR-55, and is found to be 32 feet.

Once the spacing has been determined, it is possible to determine the number of check dams required for the 170-foot length of the proposed swale. However, two aspects of this computation should be noted first. One is that the spacing provided on the table represents the distance from the upstream face of one gabion to the downstream face of the other. The spacing used to compute the number of dams should therefore be based on this distance plus the width of the lower gabion row, or 35 feet. The second aspect is that the most downstream check dam will be located at the end of the proposed swale. Given the lengths of the riprap wedge and lower gabion row, the upstream face of this check dam will be 9.5 feet upstream of the swale outfall. Since the remaining balance of the swale length is 160.5 feet, the number of check dams should be computed as:

$$Number\ of\ \ dams = \frac{160.5}{35} = 4.6 \approx 5 \text{ dams}$$

At this point in the design, it may be prudent to consider the feasibility of using gabion check dams. As determined above, the total length of each check dam, including the riprap wedge, will be 9.5 feet. Thus, for 5 dams, the total length of hard revetment will be 47.5 feet, which is between one fourth and one third of the total swale length of 170 feet. This runs somewhat counter to the initially stated goal of providing a grassed swale for flows to the receiving stream. Thus, using procedures described in Chapter 5, the possibility is investigated of using turf reinforcement mats to provide a permanent lining for the swale. Although the design computations are not presented here, it is found that a Class II TRM would provide an adequate lining for the 50-year event. Further, the shear stress on the unvegetated liner for the peak 5-year discharge would be 2.98 lb/ft^2, so that an additional riprap lining on the bottom of the swale would not be required to provide erosion protection before the establishment of vegetation in the lining. In the final analysis, the selection of erosion prevention measure for this site should be based on economic considerations.

Step 4: Compute quantities for the gabion check dams: As a part of the economic considerations mentioned in the previous paragraph, it will be necessary to compute the required quantities for the construction of the gabion check dams.

Item Number 709-10.01, Gabions (12 inch), per CY:

This item number will be used for the 12-inch gabions since no specific item number is provided for this material. As determined in Step 1, the upper gabion row will consist of two 6-foot lengths on either side of the check dam. Since the top width and height of the gabion are both 12 inches, the cross sectional area will be 1.0 ft^2, and 12.0 ft^3 of gabion would be required for each check dam. This represents a total of 60 ft^3 for the five dams, which is divided by 27 to determine the final quantity of 2.22 CY.

Item Numbers 709-10.02, Gabions (36 inch), per CY:

This item number will be used for the 36-inch gabions since no specific item number is provided for this material. As determined in Step 1, the lower gabion row will have a total length of 21 feet, with an upper embedment length of 0.75 feet and a lower embedment length of 9.0 feet. Since the top width and height of the gabion are both 36 inches, the cross sectional area will be 9.0 ft^2, and 189.0 ft^3 of gabion would be required for each check dam. This represents a total of 945 ft^3 for the five dams, which is divided by 27 to determine the final quantity of 35 CY.

Item Number 709-05.06, Machined Riprap (Class A-1), per Ton:

Because the shape of the riprap wedge at each check dam will be somewhat complicated, the volume of riprap required to construct the wedge will be determined by taking cross sectional "slices" at regular intervals, as shown in Table 10EP-3. For each "slice" the height of the wedge from the channel bottom to its upper surface is computed and the cross sectional area is determined. The cross sectional area of each successive "slice" is then multiplied by the length between the slices in order to determine the total volume.

Distance from Downstream Toe (feet)	Height of Wedge (feet)	Cross Sectional Area of Slice (ft^2)	Cumulative Volume (ft^3)
0.00	0.00	0.00	0.00
0.94	0.39	2.03	0.95
1.87	0.79	4.99	3.29
2.81	1.18	8.88	6.49
3.74	1.57	13.69	10.56
4.68	1.96	19.43	15.49
5.61	2.36	26.10	21.29
6.55	2.75	33.69	**27.96**

Table 10EP-3
Summary of Computations for Volume of Riprap Wedge

Table 10EP-3 indicates that the total volume of riprap in each wedge will be 27.96 ft^3, or 1.04 CY. Thus, for 5 gabion check dams, the total volume of riprap required will be 5.18 CY. As described in Section 10.04.6, this volume should be multiplied by 1.75 Tons/CY to determine the final quantity of 9.1 Tons.

Item Number 740-10.03, Geotextile (Type III) (Erosion Control), per SY:

Since the purpose of this material is to prevent the piping of the surrounding soils into the gabions, a layer of this material should be applied wherever the gabions or riprap interface with the excavated foundation. In order to determine the fabric quantity, these areas will be examined in three parts:

- the upstream face of the gabions exposed to soil
- the bottom and sides of the gabions
- the footprint of the riprap wedge

The interface area between the gabions and the soil on the upstream side of the structure will be determined based on the average length of embedment on the sides of the structure plus the depth of embedment across the bottom of its lower row. Based on the embedment lengths determined in Step 1, the average embedment length for the upper gabion row will be 3.0 feet per side and the average length for the lower gabion row will be 4.9 feet per side. Since the area of exposure to the soil will be the average embedment lengths times the heights of the gabions, this portion of the area can be computed as:

$$Area_1 = (2\times 3\times 1)+(2\times 4.9\times 3) = 35.4 \text{ ft}^2$$

Across the bottom of the lower gabion row, the interface area will be equal to the balance of the gabion length times the upstream embedment depth, which was determined above to be 5.9 inches, or 0.49 feet. Thus:

$$Area_2 = (21-[2\times 4.9])\times(0.49) = 5.5 \text{ ft}^2$$

The sum of these two areas is 40.9 ft^2.

The area of the bottom and sides of the structure will also involve two separate computations. First, since the lower gabion row is 21 feet long by 3 feet wide, the bottom will require 63 ft^2 of material. Further, since the lower embedment length of the upper gabion row will be 4.5 feet and the row will be 1 foot wide, the total surface area for both ends of the structure will be 9.0 ft^2.

The area required for the sides of the structure is a little more complicated due to the fact that the fabric will rest on the interface between any mineral aggregate (size 57) used to fill voids rather than against the sides of the gabions themselves. In order to provide a somewhat conservative estimate, this area will be computed as the width of the lower gabion row, 3 feet, times the overall height of the structure, 4 feet. Thus, for both ends of the structure an additional 24 ft^2 will be allowed for the side material.

Thus, the total area required for the sides and bottoms of the gabions will be 96 ft^2.

The footprint area of the wedge is the most complicated to compute, due to the relatively complex shape of the structure. Thus, to determine its surface area, the wedge was again divided into a series of “slices” and the total perimeter length for each “slice” was computed, accounting for the sloped sides of the channel. These perimeter lengths were then multiplied by the distances between successive “slices” in order to determine the total footprint area. These computations are summarized in Table 10EP-4:

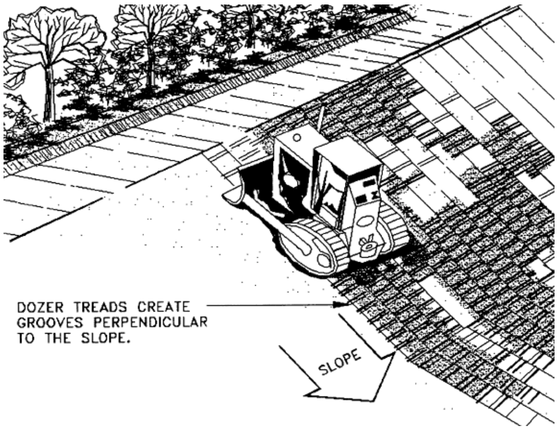
Distance from Upstream Toe (feet)	Height of Wedge (feet)	Length Along One Side (feet)	Total Length of Cross Section (feet)	Cumulative Surface Area (ft^2)
0.00	0.00	0.00	4.00	0.00
0.94	0.39	1.24	6.48	4.90
1.87	0.79	2.48	8.97	12.13
2.81	1.18	3.73	11.45	21.68
3.74	1.57	4.97	13.94	33.56
4.68	1.96	6.21	16.42	47.76
5.61	2.36	7.45	18.91	64.28
6.55	2.75	8.70	21.39	**83.13**

Table 10EP-4
Summary of Computation of Riprap Wedge Footprint Area

As can be seen from Table 10EP-4, the footprint area of a riprap wedge was found to be 83.13 ft^2.

The total of all three parts of the interface area is thus found to be 220.0 ft^2, or 24.4 SY. Multiplying this by the total number of 5 gabion check dams yields the final quantity of 122.2 SY.

10.08.1.15 SLOPE SURFACE ROUGHENING



Proper Slope Tracking
Reference: Virginia Erosion & Sedimentation Control Handbook (1992)

10.08.1.15.1 DEFINITION AND PURPOSE

Land grading involves reshaping the ground surface per the construction plans. Although graded areas with smooth, hard surfaces give an impression of a job well done, it is difficult to establish vegetation on such surfaces due to reduced water infiltration and the potential for erosion. Rough, loose surfaces provide cover for lime, fertilizer and seed. Further, niches in the surface provide for cooler and moister conditions, aiding in seed germination.

During land grading activities, surface roughening may be used to assist in stabilizing slopes on the construction site. Surface roughening consists of providing a rough soil surface to discourage slope erosion and the formation of rills. This practice reduces the potential for erosion by decreasing runoff velocities; trapping sediment; increasing infiltration of water into the soil; and aiding in the establishment of vegetative cover. A wide variety of techniques are available for this practice.

10.08.1.15.2 APPROPRIATE APPLICATIONS

Surface roughening should be used on every project where cuts or fills are required. The selection of a specific practice should be based on a number of factors:

- **Steepness of the slope:** In general, steeper slopes require greater effort in the application of erosion prevention and sediment control practices. Thus, flatter slopes are preferred where they can be accommodated by the right of way, and where they can be economically justified.

- **Mowing requirements:** Slopes which are to be mowed in the future should not be steeper than 3H:1V. In addition, the selected method of surface roughening should not create difficulties for mowing equipment due to an excessively uneven surface.

- **Cut slopes vs. Fill slopes:** Fill slopes, no matter how well compacted are usually more erodible than cuts through naturally deposited material. Thus, greater care is generally required in the selection of surface roughening technique.

- **Soil type:** Surface compaction by construction equipment, particularly on clay soils, may result in increased runoff rates from the slope and may also increase difficulty in the germination of seeded vegetation.

- **Slope length:** Even where the top of a slope is protected by a temporary berm, rainfall on a long slope can generate a significant amount of runoff. Thus, methods which serve to capture and divert this runoff are needed in addition to roughening on such slopes.

10.08.1.15.3 LIMITATIONS

None.

10.08.1.15.4 PLANNING AND DESIGN CRITERIA

Formal design for land grading practices is not required. The following criteria should be considered when selecting a surface roughening practice:

All slopes steeper than 3H:1V require surface roughening if they are to be stabilized with vegetation. Areas which have been graded but will not be stabilized immediately may be roughened to reduce runoff velocity until seeding takes place.

Roughened areas should be seeded and mulched as soon as possible to obtain optimum seed germination and seedling growth.

The simplest method of surface roughening is to forego fine grading on the face of a fill slope. As the slope is filled, soil is allowed to fall naturally onto the slope surface and is left in place to form a layer of loose, un-compacted soil 4 to 6 inches deep. Typically, this method would not apply to a cut slope. This method may be used on slopes both steeper and flatter than 3H:1V, but should be used with caution on slopes where mowing is anticipated in the future. This method is not recommended for slope lengths exceeding 100-feet.

Surface roughening may also be achieved by “grooving” the surface; that is, cutting shallow grooves into the face of the slope by means of discing, harrowing, raking or seed-planting machinery. The grooves should be placed along the contour, be at least 1 inch deep and not further than twelve inches apart. This method may be applied on slopes of any steepness, so long as the equipment used to cut the grooves will be stable when running parallel to the slope contours. In addition, it is suitable for slopes which are to be mowed in the future. This method may be applied to clays or other compressible soils, provided that equipment on pneumatic tires is used. This method is not recommended for slope lengths exceeding 100 feet.

Furrowing is another form of surface roughening. It differs from grooving in that the furrows cut into the slope are deeper and further apart. In addition, the furrows are capable of intercepting a small amount of runoff and diverting it across the slope. The furrows should be a minimum of 6 inches deep, and should not be more than 40 feet apart. In addition, they should be either parallel the contour of the surface, or slope gradually to an erosion-resistant waterway. This practice may be applied on slopes of 3H:1V or flatter and should be used with caution where mowing is anticipated in the future. This method may also be applied to clays or other compressible soils, when the equipment used to cut the furrows is on pneumatic tires. This method is not recommended for slope lengths exceeding 200 feet.

"Tracking" by equipment is another method of achieving surface roughening. This method consists of running a tracked piece of equipment, such as a bulldozer on the slope to leave horizontal depressions in the soil. Tracking should be accomplished by running tracked machinery up and down the slope, gradually working across the slope from one side to the other. This method is not preferred where other methods to roughen the surface are available, and is not recommended on clay soils due to the possibility of compaction. Soils with a high sand content are not as easily compacted, and are more suitable for tracking. On any soil, the equipment should make as few passes as possible to minimize compaction. This method is suitable for slopes which are to be mowed in the future, but may also be used on slopes steeper than 3H:1V. This method should not be applied on slopes longer than 100 feet.

10.08.1.15.5 EXAMPLE APPLICATION

No formal design or quantities are required and therefore are not presented here.

10.08.1.16 SEEDING

Applied Seeding with Mulch
Location: SR-15/US-64, Wayne County, TN (2011)

10.08.1.16.1 DEFINITION AND PURPOSE

Temporary seeding involves quickly establishing a temporary vegetative cover on exposed areas which will be disturbed again during a later part of the project. This practice involves relatively little surface preparation and utilizes grass mixtures which germinate and grow quickly. Because permanent seeding establishes the final vegetative cover for a site, it requires the replacement of topsoil and other preparation of the surface prior to the placement of seed. Permanent seeding also utilizes different grass mixtures which are more suitable for permanent cover.

Seeding with mulch reduces erosion by stabilizing disturbed areas, reducing stormwater runoff velocity, promoting infiltration, reducing problems associated with mud and dust, and improving soil conditions for permanent seeding. Mulch provides erosion protection while the seed is germinating, promotes germination of the seed, and protects the seed from birds.

10.08.1.16.2 APPROPRIATE APPLICATIONS

Temporary seeding is applicable on disturbed areas which will be left idle for more than 14 days, but are not yet at final grade. Permanent seeding should be applied only when the final grade has been established. Additionally, temporary seeding (normally with mulch) may be used when an area is cleared and grubbed of its pre-construction vegetation, but significant project grading will not begin for more than 14 days from the date of the clearing and grubbing operations.

10.08.1.16.3 LIMITATIONS

Temporary seeding and mulch should not be used if construction activities on the area will be resumed within 14 days.

10.08.1.16.4 PLANNING AND DESIGN CRITERIA

Formal design is not required. As with any other measure required by the standard drawings or standard specifications, it is not necessary to specifically indicate areas for permanent or temporary seeding the EPSC plan sheets.

Temporary seeding should be applied on the appropriate portions of the site as soon as practicable, but no more than 7 days after construction activities have been suspended. Temporary vegetative measures should be coordinated with permanent measures to assure economical and effective stabilization. It is preferable to plan grading operations to minimize the use of temporary seeding.

Seeding, mulching, fertilization, and irrigation shall meet the requirements of Tennessee Department of Transportation Standard Specifications for Road and Bridge Construction (latest edition).

Seeding shall be paid for under the following item numbers:

- 801-01, Seeding (With Mulch), per Unit
- 801-01.07, Temporary Seeding (With Mulch), per Unit
- 801-02, Seeding (Without Mulch), per Unit
- 801-02.08, Temporary Seeding (Without Mulch), per Unit
- 801-02.15, Fertilizer, per Ton
- 801-03, Water (Seeding & Sodding), per MG

Temporary and permanent seeding with or without mulch is measured by the Unit, which corresponds to 1,000 ft^2.

The computation of a quantity for seeding will usually involve consideration of both the area to be seeded and the number of stages in the proposed project. That is, if temporary seeding is to be applied more than once to a given area, the quantity would be computed as:

$$Total\ Seeding\ (Units) = \frac{Total\ Area\ (ft^2) \times Number\ of\ Times\ Seeded}{1000\ (ft^2/Unit)}$$

The quantities of water and fertilizer required may be computed as described in Section 4-801 of the Roadway Design Guidelines. The notation “MG” refers to 1000 gallons.

10.08.1.16.5 EXAMPLE APPLICATION

Given: A proposed project calls for the horizontal and vertical realignment of an existing roadway. The roadway cross section consists of two 12-foot lanes and two 6-foot shoulders. The project is one mile long and the average width of the construction limits is 96 feet. In addition, the project will involve extensive utility relocation, and the maintenance of traffic plan calls for a number of temporary run-arounds. Thus, it is estimated that most exposed areas will require at least two applications of temporary seeding.

Find: Calculate the seeding quantities required for this project.

Solution:

Step1: Determine the area: The average width of construction is 96 feet, of which 36 feet will be paved. Thus, seeding will be required on a net width of 60 feet across the project. The area for seeding can therefore be computed as:

$$Area = Length \times Width = 1\text{mile}\left(\frac{5280\,\text{ft}}{1\text{mile}}\right) \times 60\text{ft} = 316{,}800 \ \text{ft}^2$$

Step2: Determine the quantities: As discussed above, it is estimated that the disturbed areas in this project will require two applications of temporary seeding. While the contractor may not need to apply temporary seeding to the whole project two times, he may disturb some areas more than twice so that the overall average will come out to two.

<u>Item Number 801-01.07, Temporary Seeding (with Mulch), per Unit</u>

The quantity for this pay item may be computed as:

$$\frac{Area\ of\ Seeding \times Number\ of\ Applications}{1000\,\text{ft}^2/\text{unit}} = \frac{316{,}800\,\text{ft}^2 \times 2}{1000\,\text{ft}^2/\text{unit}} = 633.4 \approx 634 \ \text{units}$$

<u>Item Number 801-01, Seeding (with Mulch), per Unit</u>

Since permanent seeding will be required only one time, the quantity for this item will be half of the quantity computed for temporary seeding, or 317 units.

<u>Item Number 801-02.15, Fertilizer, per Ton</u>

Fertilizer should be applied each time an area is seeded. Because this project will require two applications of temporary seeding along with the permanent seeding, this quantity should be based on three applications of seed:

$$\frac{Area\ of\ Seeding \times Number\ of\ Applications}{1000\,\text{ft}^2/\text{unit}} = \frac{316{,}800\,\text{ft}^2 \times 3}{1000\,\text{ft}^2/\text{unit}} = 950.4 \approx 950 \ \text{units}$$

As described in the Standard Specifications, fertilizer is to be applied at the rate of 20 pounds per unit. Thus, the quantity for fertilizer may be computed as:

$$950\ units \times \frac{20\ lbs}{unit} \times \frac{1\ ton}{2000\ lbs} = 9.5 \ \text{tons}$$

<u>Item Number 801-03, Water (Seeding & Sodding), per MG</u>

Section 4-801.10 of the Roadway Design Guidelines indicates that 0.1 MG of water is required for each unit of seeding. Thus, the final quantity for water will be 95.0 MG.

10.08.1.17 SOIL STABILIZATION

Applied Soil Stabilization
Photo courtesy of Caltrans Guidance for Temporary Soil Stabilization (2003)

10.08.1.17.1 DEFINITION AND PURPOSE

Soil stabilization is utilized to assist in preventing erosion on seeded or unseeded exposed soils. They are usually categorized in terms of the method they use to prevent erosion:

- **Tackifiers** are used to help hold mulch in place over temporary or permanent seeding. They may also be applied directly to exposed soil as a means of dust control.
- **Bonded Fiber Matrix** consists of a layer of elongated fibers derived from wood, cotton, or other materials which are bound together by a water-resistant bonding agent or tackifier. This forms a crust on the surface which absorbs water and resists the force of raindrop impact. Seed and mulching materials are often incorporated into this measure as it is applied.
- **Soil Binders** are chemical agents which flocculate (bind together) soil particles to either form a hard surface or increase the effective soil particle size. They are typically used alone to provide surface protection for exposed soils. In most cases, they are not used in conjunction with seeding although they could be.

Several products shown on the Qualified Products List may be used for soil stabilization. However, the designer should be aware that there is considerable overlap between these products.

10.08.1.17.2 APPROPRIATE APPLICATIONS

Soil stabilization is applicable where assistance is needed to prevent the displacement of mulch by floatation or wind, or to provide erosion protection for graded areas which will be left idle for only a few days. Section 801.07 of the "Standard Specifications for Road and Bridge Construction" indicates part of the standard procedure for mulching is that "hay and straw mulch shall be held in place by emulsified asphalt or other commercially available tackifier." When type I or II erosion control blankets are specified in the plans the contractor may select a bonded fiber matrix from the Qualified Products List (QPL) to use in its place. Based on site conditions and engineering judgment the designer may specify a soil stabilization method in the plans.

Soil stabilization measures are effective only for raindrop impact or sheet flow and should not be applied where any type of concentrated flow would be expected. Thus, they should be applied on flat areas or on slopes up to 2H:1V. To date, research on a maximum allowable slope length is inconclusive; therefore, soil stabilization measures should be applied on slopes no more than 80 feet in length.

Tackifiers and Bonded Fiber Matrix may also be used at locations where other stabilization measures have not been effective in holding the straw in place. Using tackifiers to hold mulch in place is considered a standard procedure according to the current version of TDOT's standard specifications.

10.08.1.17.3 LIMITATIONS

Most soil stabilization measures require a 24-48 hour drying or curing time and should not be applied when there is a threat of rainfall. In addition, they should not be applied when temperatures are expected to be below approximately 40° F. This should be a consideration for projects which are expected to take place during winter months.

A number of soil stabilization measures function at least in part by forming a crust on the surface. Thus, they should not be applied in areas subject to vehicular or pedestrian traffic.

Soil stabilization measures are usually applied by spraying from a truck. Thus, they should not be specified for areas which are inaccessible to vehicular traffic. The designer should also consider the range of the pumping equipment used to apply the materials.

10.08.1.17.4 PLANNING AND DESIGN CRITERIA

Formal design is not required. In selecting the type of soil stabilization to be applied, the designer should carefully consider the soil types present at the site, the availability of water for mixing and applying the materials and the site-specific conditions which necessitate the use of soil stabilization.

Tackifiers are derived from plant-based or other organic materials. They usually consist of a combination of two or more colloidal compounds or starches, and some incorporate a flocculent such as polyacrylamide (PAM). As the name implies, these materials bind mulch to the soil surface. They also retain moisture in order to encourage the germination of grass seed, but may require reapplication as they typically remain effective for about three months.

Bonded fiber matrix consists of fibers derived from wood, cotton or other materials that are bound by some form of tackifier agent. It is usually applied as a slurry of water, fibers, seed and fertilizer. Once dry, the matrix retains moisture to provide an environment that encourages seed germination and growth. Bonded fiber matrix is intended to be biodegradable, but will usually remain effective anywhere from 3 to 12 months, depending on the materials used.

Soil binders act by electrostatically binding to soil particles together to form either a hard shell or clumps. They can consist of various polymer compounds derived from either plant-based materials or organic chemicals, including PAM which is described in Section 10.08.1.18. These materials are short-lived and will degrade in a matter of a few weeks into environmentally harmless decay byproducts. Soil binders are rarely used on TDOT projects and require the approval of the Design Manager.

On slopes, the soil stabilization measures discussed in this section are usually applied in conjunction with Slope Surface Roughening as described in Section 10.08.1.

Soil Stabilization shall be paid for under the following item numbers:

- 209-09.16, Tackifier Powder, per Lb
- 209-09.17, Tackifier Liquid, per Gal
- 209-09.18, Soil Binder Powder, per Lb
- 209-09.19, Soil Binder Liquid, per Gal
- 801-01.13, Bonded Fiber Matrix Hydromulch (Without Seed), per Unit

Bonded Fiber Matrix is measured by the Unit, which corresponds to 1,000 ft^2.

Where Bonded Fiber Matrix is specified, pay items will also be needed for seeding (either temporary or permanent) without mulch, fertilizer and water. Where tackifiers or soil binders are specified, the additional pay items will include seeding (either temporary or permanent) with mulch, fertilizer and water.

The computation of a quantity for soil stabilization measures will usually involve consideration of the area to be seeded, the longevity of the measure, and the number of EPSC stages in the proposed project. Thus, the quantity would be computed as:

$$Hydromulch\ (Units) = \frac{Total\ Area\ (ft^2) \times Number\ of\ Times\ Seeded \times Number\ of\ Applications}{1000\,(ft^2/Unit)}$$

10.08.1.17.5 EXAMPLE APPLICATION

Given: Due to right of way constraints, the topsoil stockpile for a proposed project must be located within 100 feet of a sediment impaired stream. Although the stockpile will be seeded and surrounded with Silt Fence with Backing, it is decided to provide an extra level of protection by specifying some form of soil stabilization. The stockpile area is to be located adjacent to the proposed roadway and cover an area 100 feet by 150 feet. It is also estimated that the stockpile will have to remain in place for 12 months.

Find: Determine the type of soil stabilization to be used and calculate the required quantity.

Solution:

Step1: Select the type of Soil Stabilization: The proposed stockpile site will be located adjacent to the proposed roadway, and be parallel to it. Thus, it will be possible to bring a spray truck to the site and reach the far side of the stockpile with the spray. Given the relative remoteness of the site, it is judged that the cost of the measure can be minimized by reducing the number of required applications. Because of its longer functional life, a bonded fiber matrix is selected for the site. Further, based on discussions with potential vendors, it is decided that a wood-based Bonded Fiber Matrix would the most economical for this site.

Step2: Determine the quantity: Although the functional life of different types of Bonded Fiber Matrix can vary widely, it is judged that the functional life of the measure in the proposed setting will be about 6 months. Further, it is judged that the stockpile will not be affected by construction phasing. Thus, two applications of Bonded Fiber Matrix will be required.

<u>Item Number 801-01.13, Bonded Fiber Matrix Hydromulch (Without Seed), per Unit</u>

The quantity for this pay item may be computed as:

$$\frac{Area\ of\ Seeding \times Number\ of\ Phases \times Number\ of\ Applications}{1000\,\mathrm{ft}^2/\mathrm{unit}} = \frac{(100 \times 150)\mathrm{ft}^2 \times 1 \times 2}{1000\,\mathrm{ft}^2/\mathrm{unit}} = 30\ \text{units}$$

As described above, additional pay items for temporary seeding without mulch, water and fertilizer should also be computed for this site.

10.08.1.18 POLYACRYLAMIDE

PAM used to Settle Fine Sediments
Photo courtesy of NC Erosion and Sediment Control Planning and Design Manual (2009)

10.08.1.18.1 DEFINITION AND PURPOSE

Polyacrylamide (PAM) is a polymer of acrylamide monomer units. Because the individual units can be assembled in a large variety of configurations, many different forms of PAM exist, each form having unique chemical properties. As discussed below, only anionic forms of PAM are permissible for TDOT projects. These forms of PAM have a net negative charge and are thus able to electrostatically bind to fine soil particles such as silts or clays in a process known as flocculation. This greatly increases the effective particle size of the soil so that they either are more difficult to erode from a graded area or settle more quickly in a measure such as a sediment basin.

10.08.1.18.2 APPROPRIATE APPLICATIONS

There are two primary applications of PAM. First, it can be applied to graded areas or slopes in order to cause soil particles to bind together. For example, PAM powder can be applied to jute mesh when used with a temporary sediment tube along the contour of a slope. The larger effective particle size increases the resistance of the soil to erosion, and creates a more open soil texture. This results in a reduction of soil loss and provides an improved environment for the germination and growth of grass seed. PAM applied to graded areas is usually in the form of a liquid or powder.

The second application of PAM is in ditches or other areas of concentrated flow. In this situation, the chemical is introduced into the flow in the form of a solid log or gel which is slowly dissolved as the water passes over it. These flows must then be directed into a sediment basin or other form of BMP which functions by allowing sediments to settle. The PAM released from the log binds the suspended sediment particles together into larger “flocs” which then settle at an increased rate. PAM can be used in variety of ways such as: a PAM mixing zone prior to the flow entering a sediment trap or basin, PAM applied to jute mesh to cover check dams, or PAM applied to jute mesh to create baffles in a sediment basin.

Normally, PAM is applied in conjunction with mulched seeding or as a constituent in another soil stabilization measure. However, it can be applied by itself to graded areas which will be left idle for less than 14 days and would not otherwise receive mulched seeding.

10.08.1.18.3 LIMITATIONS

There are a number of different formulations of PAM. However, only anionic forms of PAM are permissible for TDOT projects. In addition, the polymer must be in a linear form and be of sufficient purity to meet EPA and FDA standards for the treatment of drinking water or food.

PAM should not be applied to slopes which drain directly into a water resource such as a stream or wetland. It also should not be applied in any area within 30 feet of any such resource.

PAM may not be directly applied to any natural water resource.

10.08.1.18.4 PLANNING AND DESIGN CRITERIA

Formal design is not required. Application rates should be verified through the vendor or supplier and strictly followed. The following factors should be considered when determining the use of polymers on a construction project:

- The site is within the watershed of an Outstanding Resource Water or Exceptional Tennessee Water
- The site drains to an environmentally sensitive area, such as critical habitat
- Site characteristics such as slope, soil type, and proximity to water, which might lead to excessive erosion and discharge of turbid stormwater

Each project must be evaluated for its responsiveness to polymer applications. The following are instructions developed for using PAM on a project:

- Ensure Polyacrylamide (PAM) emulsions and powders are of the anionic type only and meet the following requirements:
    - Meets the EPA and FDA acrylamide monomer limits of equal to or greater than 0.05% acrylamide monomer.
    - Density of 10% to 55% by weight and molecular weight of 16 to 24 Mg/mole.
    - Mixture is non-combustible.
    - Contains only manufacturer-recommended additives.
- PAM shall be mixed and/or applied in accordance with all Occupational Safety and Health Administration (OSHA) Material Safety Data Sheet (MSDS) requirements and the manufacturer’s recommendations for the specified use conforming to all federal, state and local laws, rules and regulations.
- All vendors and suppliers of PAM, PAM mix or blends shall present or supply a written toxicity report which verifies that the PAM, PAM mix or blend exhibits acceptable toxicity parameters which meet or exceed the EPA requirements for the state and federal water quality standards. Whole effluent testing does not meet this requirement as primary reactions have occurred and toxic potentials have been reduced.
- Cationic forms of PAM are not allowed for use under this guideline due to their high levels of toxicity to aquatic organisms. Emulsions shall never be applied directly to

stormwater runoff or riparian waters due to surfactant toxicity. Contractor must seek the approval of the EPSC Design Engineer and TDOT if Chitosan is proposed for use on this project.
- All vendors and suppliers of PAM, PAM mix or blends shall supply written "site specific" testing results demonstrating that a performance of 95% or greater reduction of NTU or TSS from stormwater discharges.
- Emulsion batches shall be mixed following recommendations of a testing laboratory that determines the proper product and rate to meet site requirements. Application method shall insure uniform coverage to the target area. (Emulsions shall never be applied directly to stormwater runoff or riparian waters).
- Dry form (powder) may be applied by hand spreader or a mechanical spreader. Mixing with dry silica sand will aid in spreading. Pre-mixing of dry form PAM into fertilizer, seed or other soil amendments is allowed when specified in the design plan. Application method shall ensure uniform coverage to the target area.
- Block or Log forms shall be applied following site testing results to ensure proper placement and performance and shall meet or exceed state and federal water quality requirements. Place anionic gel logs at the inlet to ponds and traps onsite, or other locations where flow and mixing are optimal. Post-treatment settling or filtration is required. The number of logs to use will be determined by the EPSC Design Engineer and/or EPSC Inspector.

Tests have shown that the addition of PAM can significantly improve the performance of mulched seeding on graded areas, both in terms of the amount of soil eroded and in terms of the rate of germination and growth of grass seed.

Runoff from graded areas treated with PAM should not be directly released from the site. Rather, such runoff should be passed through appropriate sediment control BMP's before it is allowed to leave the site. Typical sediment control BMP's which may be used to treat this runoff include a Sediment Basin, Sediment Trap with Check Dam or a series of Enhanced Check Dams. PAM should not be applied until all of the needed structural BMP's have been installed.

PAM logs or gels are not a substitute for the installation of sediment controls in a ditch or concentrated flow. Rather, they should be used in conjunction with ditch checks or other BMP's located upstream of the PAM log installation.

Polyacrylamide shall be paid for under the following item numbers:

- 209-09.21, Polyacrylamide Gel Logs, per Each
- 209-09.22, Polyacrylamide Powder, per LB
- 209-09.23, Polyacrylamide Liquid, per Gallon

The specific formulation of anionic PAM to be used on a site is based on an evaluation of the project site during construction by the product vendor. Thus, the designer may not know whether a liquid or powdered form of the material will be applied for a given project. The ESPC quantities should include both liquid and powder PAM as alternates. In addition, all PAM items should include a footnote with the quantities tabulation indicating the quantity of PAM may increase or decrease based on field conditions.

Application rates for PAM on graded areas will also be determined by the vendor during construction. In general, application rates for slopes will be greater than for flat areas. When more specific data is not available for developing quantity estimates, the designer may use a rate of 20 Lb/acre for powdered PAM and 2.0 Gal/acre for liquid PAM on slopes less than 3:1. For slopes 3:1 and greater the designer may use a rate of 30 Lb/acre for powdered PAM and 3.0 Gal/acre for liquid PAM. The polymers that compose an application of PAM will be decomposed by exposure to sunlight and air. Although the functional life of an application of PAM is affected by a number of variables, a conservative estimate is that a re-application of PAM will be needed after about 3 months.

The quantity for PAM logs or gels in concentrated flows should be based on the amount of rainfall that would normally occur during the expected period of construction. The vendor of a specific product should provide information on the volume of water that can be treated by a single log. When it is not possible to obtain this information, a value of 1.3 acre feet per log may be used. The example application below provides more details on how to make this calculation.

10.08.1.18.5 EXAMPLE APPLICATION

Given: A proposed pavement replacement project located in Robertson County will include an area 2300 feet long which will drain to a stream listed as Exceptional Tennessee Waters. Because of this, the designer has decided to place a sediment basin at the outfall to the stream and to utilize PAM to help control the fine sediments in runoff during construction. Thus, PAM will be applied to graded areas beyond the roadway bed and PAM logs will be placed in the ditch just upstream of the sediment basin. The typical cross section of the roadway will consist of four 12-foot lanes with 12-foot shoulders and a 30-foot wide center median. The average width of the disturbed area will be 188 feet and the construction is estimated to require 6 months.

Find: Determine the quantities for treatment of the site with PAM.

Solution:

Step1: Determine the quantity for the graded areas: Is decided to base this estimate on the powdered form of PAM.

Item Number 209-09.22, Polyacrylamide Powder, per Lb.

The proposed typical cross section will be 102 feet wide, including the shoulder widths. Thus, the graded areas beyond the roadway bed will have a total width of 86 feet. The quantity of PAM required for a single application to these areas can calculated as:

$$\frac{86\ ft \times 2300\ ft}{43{,}560\ ft^2/acre} \times \frac{20\,Lbs}{acre} = 90.8\ \text{lbs}$$

Since the average functional life of an application of PAM is approximately 3 months, it will be necessary to provide 2 applications, for a total quantity of 181.6 pounds.

Step2: Determine the quantity for PAM logs: This quantity should be based on the expected quantity of runoff into the sediment basin. In contrast to other types of EPSC measures, PAM logs are not designed for a single event such as the 5-year, 24-hour storm.

Rather, they are intended to dissolve slowly in the runoff generated by day-to-day rainfall events. Thus, the quantity will be estimated based on the normal precipitation expected to occur over the life of the project. Based on data published on the Internet by NOAA, the designer had determined that the normal annual rainfall for Nashville (the closest station) is 40.11 inches per year. Since this project is expected to have a duration of 6 months, the quantity estimate will be based on half of the normal annual rainfall, or 24.06 inches. In order to provide a conservative estimate, it is assumed that all of this rainfall will become runoff into the sediment basin.

The total drainage area generating runoff to the sediment basin is computed as:

$$Area = \frac{188\ ft \times 2300\ ft}{43{,}560\ ft^2 / acre} = 9.93 \text{ acres}$$

Thus, the total quantity of runoff to use for the quantity estimate may be computed as:

$$Runoff = \frac{9.93\,ac \times 24.06\,in}{12\,in/ft} = 19.90 \text{ ac-ft}$$

<u>Item Number 209-09.21, Polyacrylamide Gel Logs, per Each</u>

Since no more detailed information is available, the quantity estimate will be based on 1.3 ac-ft/log:

$$\frac{19.90\,ac\ ft}{1.3\,ac\ ft/piece} = 15.3 \text{ logs} \approx 15 \text{ logs}$$

10.08.1.19 CONSTRUCTION PHASING

Construction phasing involves coordinating the construction schedule to minimize the amount of disturbed area at any given time and coordinating land clearing with the installation of erosion prevention and sediment control measures. This includes managing excavated material. Construction phasing is usually determined by the contractor; thus, it is discussed here only in general terms.

Planning the sequence of construction activities in relation to the installation of erosion prevention and sediment control measures is a key to efficient and cost-effective erosion prevention and sediment control. By clearing small sections of the project and limiting areas of disturbance, it is much easier to prevent and control erosion than if the entire site were exposed at once. Perimeter controls, sediment traps, basins, and diversions should be in place to control runoff and capture sediments before site disturbance occurs. Disturbed areas in the vicinity of water bodies, wetlands, steep grades, or long slopes, should be made a priority and be stabilized within 7 days of disturbance. Graded areas which will be left idle for more than 14 days should be immediately temporarily or permanently stabilized, rather than waiting until all project grading is complete. Excavated material which is retained within the project limits should be stockpiled near the work area and contained by an appropriate BMP. If the material is removed from the site, it should be disposed of properly. Excavated material shall not be placed in any wetlands.

Section 10.06 provides a complete discussion of this BMP in relation to the staging of Erosion Prevention and Sediment Control plans.

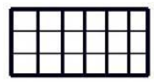
10.08.2 SEDIMENT CONTROL MEASURES

Erosion prevention measures, as described in the previous section, work to eliminate or reduce the quantity of erodible materials which are dislodged and carried away in stormwater runoff. As such, these measures form the first line of defense against pollution caused by excessive quantities of sediment being released from a construction site. The second line of defense is to capture these eroded sediments so that they can be retained on the site. The BMPs described in this section are primarily used to form this second line of defense. They serve to capture sediment either by filtering it from on-site runoff or by slowing flow velocities to allow sediments to settle out. A few of these practices employ both mechanisms. In addition, these BMPs serve to isolate a construction project from surrounding areas, thus protecting undisturbed areas and preventing off-site storm runoff from entering the construction site.

This section describes best management practices which may be used on TDOT projects to retain mobilized sediment on site. It also provides guidelines on where and how to apply these practices. These measures can be combined with the erosion prevention measures provided in Section 10.08.1 to develop an effective Erosion Prevention and Sediment Control plan.

10.08.2.1 DEWATERING STRUCTURE (EC-STR-1)

Dewatering Structure
Location: SR-448, Sevier County, TN (2004)



DEWATERING STRUCTURE

10.08.2.1.1 DEFINITION AND PURPOSE

A dewatering structure is a sediment control device that combines riprap and geotextile fabric to settle and/or filter sediment laden water which has been pumped from an excavated work area. Slurry water is pumped out of such areas and is discharged into the structure before being released from the site. The storage volume offered by the structure allows water to be held until the sediments can drop out. Further, sediments can be filtered from the water as it passes through the geotextile fabric.

10.08.2.1.2 APPROPRIATE APPLICATIONS

A dewatering structure may be used whenever sediment laden water is removed from an area by means of pumping. It should be used in conjunction with dewatering operations for cofferdams, trenches, enclosed ditches, and other construction activities which require the removal of sediment laden water. It is an alternative for sediment filter bags.

10.08.2.1.3 LIMITATIONS

Dewatering structures should not be placed within a jurisdictional wetland or within 15 feet of a stabilized outlet, stream, or other natural water resource.

When filtered water from the dewatering structure will discharge into Exceptional Tennessee Waters or a sediment-impaired stream, the minimum installation distance from the top of bank shall be 30 feet.

Use requires a flat or gently sloped area for placement and use.

10.08.2.1.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is not required. However, for each dewatering structure used the dimensions should be labeled in the EPSC Plans.

The following guidelines should be used when planning and designing dewatering structures as described in Standard Drawing EC-STR-1.

A dewatering structure should be sized to allow pumped water to flow through the filtering device without overtopping the structure. The geotextile fabric used around the inside perimeter of the structure should be anchored and staked into existing ground as shown in the standard drawing.

The minimum required volume of storage in cubic feet for a dewatering structure is obtained by multiplying the pumping rate (in gallons per minute) by 16, as shown in the table on Standard Drawing EC-STR-1. The recommended volume is based on 2 hours of pumping at the full rate shown on the drawing. In situations where it is likely that a pump will be operated for longer periods of time, the volume of the structure should be appropriately increased.

The minimum dewatering structure volumes provided in Standard Drawing EC-STR-1 are based on assuming that the structure will be horizontal. Where the structure is to be placed in a sloping area, the available storage capacity will be reduced. It may be necessary to increase the size of the structure to compensate for this.

The geotextile fabric (Type II) used in a dewatering structure shall meet the requirements of the standard specifications for geotextiles, AASHTO designation M-288, Sediment Control.

The maximum height of the dewatering structure is 30 inches. Therefore, when placing a dewatering structure, the designer should consider the area available within the Right-of-Way. If the available area is less than that required for the structure, a construction easement may be required for the construction and maintenance of the structure.

An optional excavated area may be added to a dewatering structure to provide storage area for sediments trapped within the structure. Where it is included, this excavated area should be a minimum of 3 feet deep. Since the excavated area will be below grade, any water collected in it may not drain out in between times that the pump is operated. Therefore, the volume of this area should not be included in computing the storage volume offered by the dewatering structure.

Silt fence with wire backing should be provided on the down-slope side of a dewatering structure, across its entire width. This fence will serve to filter any sediment remaining in the water released from the dewatering structure. Off-site stormwater runoff should be diverted away from all dewatering structures.

Once the water level nears the top of the structure, the pump should be turned off while the structure drains down to the elevation of the excavated area. The remaining water may be removed only after a minimum of 6 hours of sediment settling time. This effluent should be pumped across an area with established vegetation or through a silt fence with wire backing prior to entering a watercourse.

The existing vegetative buffer should remain between the silt fence with wire backing and the stabilized outlet, stream, or other natural water resource. The desirable vegetative buffer to maintain when placing this structure adjacent to most streams shall be 30 feet, measured from the top of the stream bank to the silt fence with wire backing. The minimum buffer distance shall be 15 feet. For locations where the dewatering structure will discharge to Exceptional Tennessee Waters or a sediment-impaired stream, the desirable distance shall be 60 feet, with a minimum distance of 30 feet. At all sites, the designer should attempt to maintain the desirable vegetative buffer.

Dewatering structures shall be paid for under the following item numbers

- 203-01, Road & Drainage Excavation (Unclassified), per CY
- 209-05, Sediment Removal, per CY
- 209-10.01, Temporary Dewatering Structure, per CY

Silt fence with wire backing shall be paid for according to its respective standard drawing.

10.08.2.1.5 EXAMPLE APPLICATION

Given: The designer has determined that three dewatering structures will be required for the construction of a proposed box culvert.

Find: Calculate the quantities required for these dewatering structures.

Solution: The pay items to be used for these dewatering structures are:

Item Number 209-10.01, Temporary Dewatering Structure, per CY

A general note on Standard Drawing EC-STR-1 indicates that dewatering structures shown in the EPSC plans should be designed assuming the use of a 4 inch construction pump. As shown in the table, the required dewatering structure volume for a 4 inch pump is 8000 CF. This required volume may be converted to cubic yards as:

$$V = 8000\, ft^3 \left(\frac{1\, yd^3}{27\ ft^3} \right) = 296.30 \approx 296 \text{ CY}$$

Thus, the three structures will require a total volume of 889 CY.

Item Number 209-08.02, Silt Fence (with Backing), per LF

To determine the required quantity of silt fence with wire backing, it is first necessary to determine the size of the dewatering structures. Since the required storage volume of 8000 CF is to be provided within a depth of 30 inches (2.5 feet), the area inside the dewatering structure may be computed as:

$$Area = \frac{8000}{2.5} = 3200 \text{ SF}$$

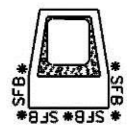
Based on inspection of the site, it is determined that the area inside of the dewatering structures will be 50 feet by 64 feet, with the long dimension parallel to the creek. The outside dimension of the structure must take into account the width of the riprap placed around the perimeter. Since the riprap is to be placed at a 2H:1V slope, a distance of 5 feet will be required to build a wall 30 inches high. In addition, a 2-foot shelf is required at the top of the riprap wall, for a combined width 7 feet. Thus, the outside dimension of the structure will 14 feet greater than the inside dimension, for a total of 78 feet. It is estimated that an additional 7 feet of length will be required to wrap the corners of the structure as shown in the standard drawing. Thus, the total length of silt fence required for each structure will be 85 feet. The final quantity for silt fence with wire backing will be three times this length, or 255 feet.

Item Number 209-05, Sediment Removal, per CY

Sediment Removal is paid for per project and is thus not described in detail here.

10.08.2.2 SEDIMENT FILTER BAG (EC-STR-2)

Sediment Filter Bag
With Silt Fence & Stream Buffer



10.08.2.2.1 DEFINITION AND PURPOSE

A sediment filter bag is a temporary sediment control structure made of heavy weight, UV-resistant polypropylene geotextile fabric that is sewn into a large completely enclosed bag. Sediment laden water can be pumped from an area being dewatered into a filter bag, which serves to retain the sediments while allowing water to pass through the fabric. The water released from a filter bag will usually retain a relatively large amount of fine sediments. Thus, this water is directed through a second filter, usually silt fence with wire backing, before being released from the site.

10.08.2.2.2 APPROPRIATE APPLICATIONS

A sediment filter bag may be used whenever sediment laden water is removed from an area by means of pumping. It should be used in conjunction with dewatering operations for coffer dams, trenches, enclosed ditches, and other construction activities which require the removal of sediment laden water. It is an alternative for dewatering structures.

10.08.2.2.3 LIMITATIONS

A sediment filter bag should not be placed within a jurisdictional wetland or within 15 feet of a stabilized outlet, stream or other natural water resource. When filtered water from the sediment bag will discharge into Exceptional Tennessee Waters or a sediment-impaired stream, the minimum installation distance from the top of bank should be 30 feet.

A filled sediment bag can weigh as much as 7 tons. The designer should ensure that there will be adequate access for the equipment necessary for the disposal of the bag.

Use requires a flat or gently sloped area for placement and use.

10.08.2.2.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is not required. However, for each sediment filter bag used the size of the bag should be labeled in the EPSC plans. The following guidelines should be considered when using a sediment filter bag in the EPSC plans.

A sediment filter bag should be placed on a level pad a minimum of 6 inches thick composed of mineral aggregate (size 57). This pad should be constructed on an area with sufficient slope to allow water entering the pad to drain away from the project work area. However, it is necessary for the pad to be level in order to prevent the bag from rolling along the slope as water is pumped into the structure. The pad, including the slopes, should be wrapped with geotextile fabric (Type III). This geotextile fabric (Type III) shall meet the requirements of the standard specifications for geotextiles, AASHTO designation M-288, Erosion Control. Off-site stormwater runoff should be diverted around the sediment filter bag location.

A sediment filter bag should be surrounded on all sides by silt fence with wire backing. Sediment Tube (EC-STR-37) or Filter Sock (EC-STR-8) may be used as alternate materials.

Where necessary, a sediment filter bag may be applied on pavement or other impervious surface. In such situations, the bag should be placed on a minimum 6-inch layer of mineral aggregate (size 57) with geotextile fabric as shown in the standard drawing. In addition, it should be surrounded by filter sock or another BMP which may be applied without trenching or staking.

Sediment filter bags used for TDOT projects may be equipped with a sleeve sufficient to accept a 4-inch pump discharge hose. Slitting the bag to make the hose connection is also acceptable.

The bag sizes shown in the pay item list are approximate only. The actual size of bag supplied for a project may vary based on the products available from a specific vendor. The minimum “footprint” of the bag shall be 150 square feet.

A sediment filter bag should be considered full once the accumulated sediments have reached a depth of 6 inches. In the filter bag shown on the standard drawing, this corresponds to approximately 4 CY of material, which can weigh as much as 7 tons. Once the bag has reached this point, it should be removed and replaced with a new one. The rate at which a bag will collect sediments depends on a number of variables, including the pumping rate, the nature of the sediments in the slurry water, and the frequency at which pumping is required. The designer should consider these factors along with the duration of the operation to estimate the quantity of bags which will be required.

In determining the location for a proposed sediment filter bag, the designer should allow sufficient room and a clear path to allow access for the equipment needed for bag removal. Bag disposal should be in a landfill or other suitable area. It will not be acceptable to open the bag and spread the collected sediments on site. Lifting and removal of the bag may be facilitated by means of the optional lifting straps shown on the standard drawing.

The desirable vegetative buffer to maintain when placing this structure adjacent to most streams shall be 30 feet, measured from the top of the stream bank to the silt fence with wire backing. The minimum buffer distance shall be 15 feet. For locations where the filter bag will discharge to Exceptional Tennessee Waters or a sediment-impaired stream, the desirable distance shall be 60 feet, with a minimum distance of 30 feet. At all sites, the designer should attempt to maintain the desirable vegetative buffer width between the top of the stream bank and the filter bag installation.

Sediment filter bags shall be paid for under the following item numbers:

- 209-09.03, Sediment Filter Bag (15' X 15'), per Each
- 209-09.04, Sediment Filter Bag (15' X 10'), per Each
- 303-10.01, Mineral Aggregate (Size 57), per Ton
- 740-10.03, Geotextile (Type III) (Erosion Control), per SY

Silt fence with wire backing shall be paid for according to its respective standard drawing.

When sediment filter bags are replaced, only the replacement bag shall be paid for. Maintenance on all other parts of the sediment filter bag assembly shall be included in the initial payment.

The quantity for mineral aggregate (size 57) is measured by the ton. However, the determination of this quantity is usually based upon computations of the volume of stone required. As described in Section 10.04.6.1, the computed volume of aggregate in CY can be converted to tons at the rate of 1.49 tons per CY.

Table 10SC-1a and 10SC-1b contain typical quantities which may be used in estimates for a single 15'x10' and 15'x15' sediment filter bag on varying slopes.

Item Number:	**209-08.02**	**303-10.01**	**740-10.03**
Ground Slope (%)	**Temporary Silt Fence (With Backing), LF**	**Mineral Aggregate (Size 57), Ton**	**Geotextile (Type III) (Erosion Control), SY**
0.0	86.0	4.5	71.9
0.5	86.2	4.8	72.4
1.0	86.4	5.1	72.8
2.0	86.8	5.8	73.8
3.0	87.2	6.5	74.5
4.0	87.6	7.1	76.0
5.0	88.0	7.8	77.2
7.0	88.8	9.2	79.3
10.0	90.0	11.4	82.7

Table 10SC-1a
Typical Quantities for a Single Sediment Filter Bag Installation
on Varying Slopes (Bag Size: 15'x10')

Item Number:	209-08.02	303-10.01	740-10.03
Ground Slope (%)	**Temporary Silt Fence (With Backing), LF**	**Mineral Aggregate (Size 57), Ton**	**Geotextile (Type III) (Erosion Control), SY**
0.0	96.0	6.6	92.1
0.5	96.3	7.3	92.9
1.0	96.6	8.0	94.0
2.0	97.2	9.5	95.6
3.0	97.8	10.9	97.4
4.0	98.4	12.4	99.1
5.0	99.0	13.9	100.9
7.0	100.2	17.1	104.7
10.0	102.0	22.0	110.6

Table 10SC-1b
Typical Quantities for a Single Sediment Filter Bag Installation
On Varying Slopes (Bag Size: 15'x15')

10.08.2.2.5 EXAMPLE APPLICATION

Given: A project requires the installation of a proposed box culvert in a perennial stream. A temporary diversion channel will be used to separate the proposed construction from the stream. Due to the length of the culvert, the designer has determined that dewatering will be necessary at both ends of the proposed box culvert. Due to site conditions, there will not be sufficient room for the construction of temporary dewatering structures. Thus, sediment filter bags will be employed. Further, the ground slope at one of the proposed filter bag locations is 2% while the ground slope at the other proposed location is 6%. The proposed construction is estimated to require about 4 weeks.

Find: Calculate the required quantities for the sediment filter bags.

Solution: Based on anticipated field conditions, it is decided to use 15' x 15' sediment filter bags. The pay items for sediment filter bags are:

Item Number 209-08.02, Temporary Silt Fence (With Backing), per LF

Table 10SC-1b indicates that 97.2 feet of fence will be required for the installation where the ground slope is 2%. Interpolating from the table for a slope of 6% yields a length of 99.6 feet for the other installation. This results in a total of 196.8 feet, which is rounded up for the final quantity of 197 LF.

Item Number 209-09.03, Sediment Filter Bag (15'x15'), per Bag

Because this project is to be conducted in a perennial stream, it is anticipated that there will be a significant flow of groundwater into the site so that pumping will be required relatively frequently. Further, the geotechnical report indicates that the materials in the channel bed are composed largely of silty sand. Thus, the pumped effluent may contain relatively large amounts of sediment. Due to these comparatively severe circumstances, it is estimated that the filter bags will need to be replaced on a weekly basis. Because the project is expected to require 4 weeks, 4 bags will be required at each location, for a final quantity of 8.

<u>Item Number 303-10.01, Mineral Aggregate (Size 57), per Ton</u>

The quantity of mineral aggregate (size 57) recommended in Table 10SC-1b for a ground slope of 2.0% is 9.5 tons. For a ground slope of 6%, a quantity of 15.5 tons can be interpolated from the table. Thus, the two locations will require 25.0 tons of aggregate, which is the final quantity.

<u>Item Number 740-10.03, Geotextile (Type III) (Erosion Control), per SY</u>

Using Table 10SC-1b as described above yields 29.5 SY of geotextile for one location and 31.7 SY for the other. This results in a total of 61.3 SY, which is rounded up for final quantity of 62 SY.

10.08.2.3 SILT FENCE (EC-STR-3B)

* SF * SF * SF * SILT FENCE

Silt Fence
Location: SR-131, Knox County, TN (2004)

10.08.2.3.1 DEFINITION AND PURPOSE

Silt fence is a sediment control measure which is used to intercept sediment transported from areas where runoff occurs as sheet flow. Silt fence is composed of woven geotextile fabric supported by steel or wood posts. The permeability of the fabric is fairly low, so that water can pass through it only slowly. This will cause stormwater runoff from disturbed areas to pool on the upstream side of the fence so that sediments can settle out, thus preventing them from leaving the construction site.

10.08.2.3.2 APPROPRIATE APPLICATIONS

Silt Fence may be used in a variety of locations including:

- at the toe of or on an exposed slope
- around the perimeter of an exposed construction site
- along the banks of ditches or swales (see Limitations, below)
- around the perimeter of a soil stockpile

This measure should be located where sheet flow runoff can be collected behind the fence without damaging either the fence or the area it submerges.

10.08.2.3.3 LIMITATIONS

Silt fence is intended for sheet flows only and should not be installed across streams, ditches, waterways, or other concentrated flow areas. It should also not be used adjacent to natural water resources such as streams, wetlands, ponds, springs, or other natural water resources. Silt fence with wire backing should be used in such applications.

10.08.2.3.4 PLANNING AND DESIGN CRITERIA

Formal design is not required. The following guidelines should in conjunction with Standard Drawings EC-STR-3B and EC-STR-3E.

Silt fence should be installed along the contour, never up or down a slope. This is essential to ensure that the fence will not accidentally concentrate stormwater flows, thus creating worse erosion problems.

Silt fence should be installed so as to be as close as possible to the ground contour. The bottom of the fence at the ground line should be on a 0% grade, plus or minus 0.5%. The ends of a run of silt fence should be turned upslope to filter any concentrated flow that might be flowing behind, and parallel to the fence.

The drainage area for a continuous fence should be 1/4 acre per 100 linear feet of fence length, up to a maximum drainage area of 2 acres. The maximum slope length behind the fence on the upslope side should be 110 feet (as measured along the ground surface). When two sections of silt fence join each other, they should be joined to form a continuous barrier per Standard Drawing EC-STR-3E.

When used at the bottom (toe) of a slope, silt fence should be installed 5 feet to 7 feet away from the toe to allow extra space for the ponding of water, collection of sediment, and for ease with maintenance and removal.

Silt fence should be located where there will be adequate access for the vehicles necessary to maintain and remove the measure.

Silt fence shall be paid for under the following item numbers:

- 209-05, Sediment Removal, per CY
- 209-08.03, Temporary Silt Fence (Without Backing), per LF

It is important to take into account the duration of a project when calculating quantities for silt fence. The expected life span of the silt fence is 6 to 12 months. Therefore, projects of long duration may require a complete replacement of the silt fence. The quantity for silt fence to be in place for a long period of time should be based on the assumption that the material will be replaced every 9 months, on the average. The staging of the Erosion Prevention and Sediment Control plan should be considered in computing this quantity, as well as the contractor's phasing plan, when it is known. The computations would thus take the following form:

$$\frac{Calendar\ Days\left(accounting\ \ for\ EPSC\ Plan\ Phases\right)}{\left(9\ months\right)\times\left(30\ days\right)} = Adjustment\ \ factor$$

The adjustment factor should be rounded to nearest whole number. The final quantity may then be computed from:

$$Computed\ Linear\ Feet\ of\ \ Silt\ Fence \times Adjustment\ Factor = Total\ Quantity, LF$$

10.08.2.3.5 EXAMPLE APPLICATION

Given: An erosion prevention and sediment control plan is being developed for a roadway widening project on a rural highway in west Tennessee. The project is 1 mile long and will utilize 6H:1V roadway side slopes. Since the project is rural and no streams are involved, the designer has determined that silt fence should be placed 5 feet from the toe of the slope. The project is expected to require 18 months.

Find: Calculate the required quantity for silt fence.

Solution:

Step1: Determine the length of silt fence: Since the project is one mile long, and silt fence will be required on both sides of the roadway, the total length of silt fence required will be:

$$2 \times 5280 = 10{,}560 \text{ LF}$$

Step2: Determine the quantities:

<u>Item Number 209-08.03, Temporary Silt Fence (Without Backing), per LF</u>

Because the proposed slopes will be left exposed for almost the entire duration of the project, the adjustment factor may be computed as:

$$\frac{365 \times 1.5}{9 \times 30} = 2.03 \approx 2$$

Thus, the final quantity is computed by multiplying the adjustment factor by the length:

$$2 \times 10{,}560 = 21{,}120 \text{ LF}$$

<u>Item Number 209-05, Sediment Removal, per CY</u>

Sediment Removal is paid for per project and is thus not described in detail here.

10.08.2.4 SILT FENCE WITH WIRE BACKING (EC-STR-3C)

* SFB * SFB * SFB * SILT FENCE WITH WIRE BACKING

Silt Fence with Wire Backing
Location: SR-250, Cheatham County, TN (2007)

10.08.2.4.1 DEFINITION AND PURPOSE

Silt fence with wire backing consists of a woven monofilament geotextile fabric reinforced with wire fencing. It may be used up-gradient to, and along the perimeter of streams, wetlands, ponds, springs, or other natural water resources located within or adjacent to the project right-of-way and at significantly large fill slopes. This measure is more durable than standard silt fence and utilizes a geotextile fabric which is much stronger and which has a finer apparent opening size. This material intercepts sediment laden sheet flow, reducing its velocity so that the suspended solids will settle out. It also serves to filter sediments from the flow as it passes through the fabric material.

10.08.2.4.2 APPROPRIATE APPLICATIONS

Silt fence with wire backing should be used where a disturbed area is located immediately adjacent to a natural water resource (i.e., a stream, wetland, etc.) and where the runoff will be mainly sheet flow. In such situations, there would be no opportunity to provide additional sediment control measures. Silt fence with wire backing provides an enhanced structural system and finer filtering capacity in an effort to maximize the quantity of sediment captured before runoff enters the water resource. This material may also be used where the upstream drainage area exceeds the maximum allowable for standard silt fence.

10.08.2.4.3 LIMITATIONS

It is intended only for sheet flows and should not be installed across streams, ditches, or other concentrated flow areas.

10.08.2.4.4 PLANNING AND DESIGN CRITERIA

Formal design is not required; however, when silt fence with wire backing is specified, the following standards should be used:

Silt fence with wire backing should be constructed according to the specifications, dimensions, and installation requirements shown on Standard Drawing EC-STR-3C and EC-STR-3E.

Because silt fence with wire backing is to be installed to intercept flow from disturbed areas that are adjacent to a natural water resource (i.e., a stream, lake, natural pond, etc.), it is usually placed along its borders.

Silt with wire backing fence should be installed along the contour, never up or down a slope. This is essential to ensure that the fence will not accidentally concentrate stormwater flows, creating worse erosion problems. Thus, the fence should be installed as parallel as possible to the ground contour. The bottom of the fence at the ground line should be on a 0% grade, plus or minus 0.5%. Only the ends of a run of silt fence with wire backing should be turned upslope to filter any concentrated flow that might be flowing behind, and parallel to the fence.

The maximum drainage area for a continuous silt fence with wire backing should be 1 acre per 150 linear feet of fence length. The slope length above the fence should be no more than 290 feet, measured along the ground surface.

When used at the bottom (toe) of a slope, silt fence with wire backing should be installed 5 feet to 10 feet away from the toe of the slope to allow extra space for the ponding of water, collection of sediment, and for ease with maintenance and removal.

The fence should be located where there will be adequate access for the vehicles necessary to maintain and remove the measure.

Silt fence with wire backing shall be paid for under the following item numbers:

- 209-05, Sediment Removal, per CY
- 209-08.02, Temporary Silt Fence (With Backing), per LF

It is important to take into account the duration of a project when calculating quantities for silt fence with wire backing. The expected life span of the silt fence with wire backing is 6 to 12 months. Therefore, projects of long duration may require a complete replacement of the silt fence with wire backing. The quantity for silt fence with wire backing, which is to be in place for a long period of time, should be based on the assumption that the material will be replaced every 9 months, on average. The staging of the Erosion Prevention and Sediment Control plan should be considered in computing this quantity, as well as the contractor's phasing plan, when it is known. The computations would thus take the following form:

$$\frac{Calendar\ Days\left(accounting\ \ for\ EPSC\ Plan\ Phases\right)}{\left(9\ months\right)\times\left(30\ days\right)} = Adjustment\ \ factor$$

The adjustment factor should be rounded to nearest whole number. The final quantity may then be computed from:

$$Computed\ Linear\ Feet\ of\ Silt\ Fence\ With\ Wire\ Backing \times Adjustment\ Factor = Total\ Quantity, \left(LF\right)$$

10.08.2.4.5 EXAMPLE APPLICATION

Given: A 1-acre area within a freeway construction project will drain to a stream which crosses the project right-of-way. The construction of the cross drain for the stream will require a temporary diversion channel, and during the time that the diversion and new culvert are being constructed, on-going grading work will occur on the 1-acre drainage area. Thus, sediment controls will be needed to provide protection for the stream during the construction of the cross drain. The right of way in this area is 150 feet wide.

Find: Select a sediment control measure for this site and estimate the required quantities.

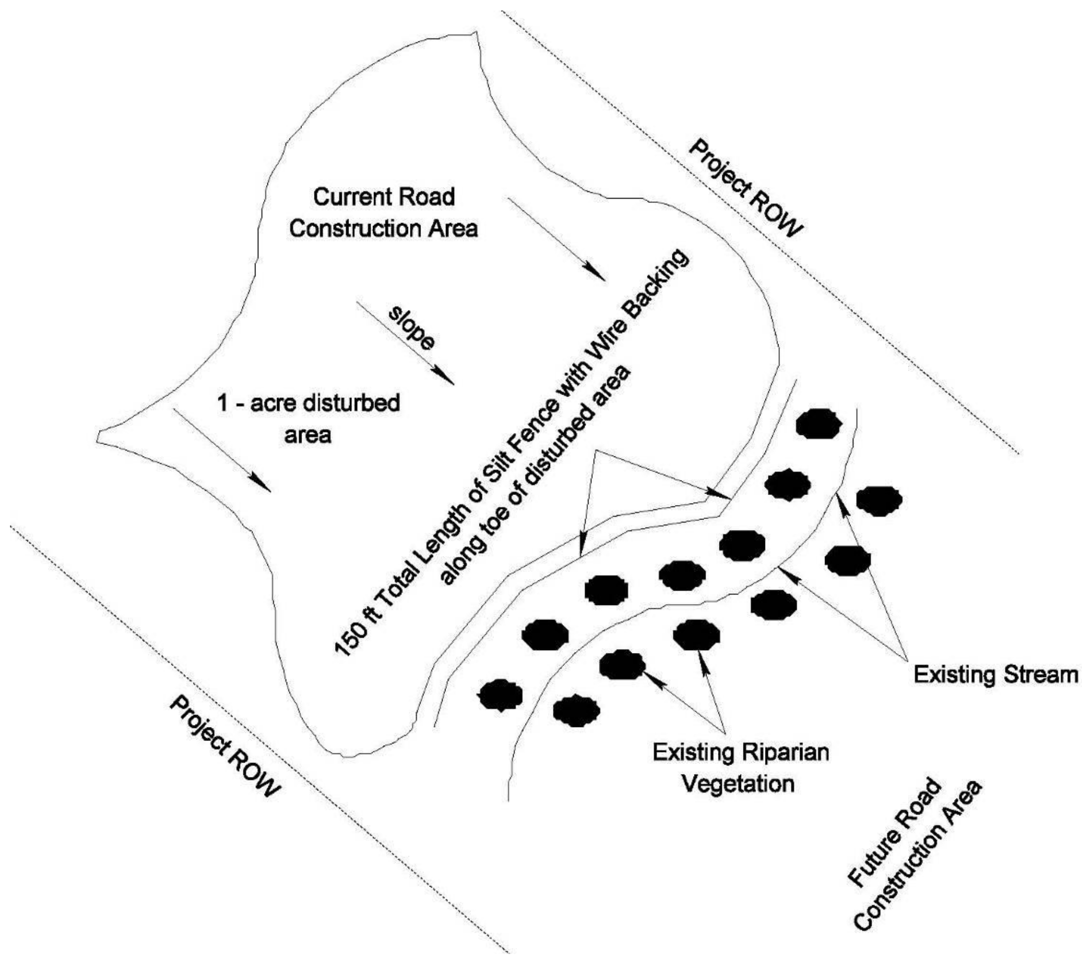


Figure 10SC-1
Site Sketch for Disturbed Area Adjacent to a Waterway

Solution: Silt fence with wire backing will be needed at this site for two reasons. First, since the 1-acre drainage area is being actively worked, it will be difficult to install or maintain structural BMPs on the disturbed areas. Thus, silt fence with wire backing is the only measure which will provide adequate sediment control across the 150 feet wide right-of-way. In addition, silt fence with wire backing is specifically intended for use adjacent to water resources such as streams.

Although the stream is not listed as an Exceptional Tennessee Water or sediment-impaired stream, the existing riparian vegetation is being allowed to remain in place as long as possible before the construction of the cross drain.

It should be noted that, had the area draining to the fence been greater than 1 acre, additional measures would have been needed to supplement the silt fence with wire backing. However, since the disturbed area is actively being worked, it would not be practical to install another row of silt fence somewhere on the slope. A better solution would be offered by specifying temporary diversion berms to redirect a portion of the runoff from the slope to stabilized side ditches along the project right of way limits.

Item Number 209-08.02, Temporary Silt Fence (with Backing), per LF

Since the fence will be used only while the new culvert for the cross drain is being constructed, it is unlikely that it will remain in place longer than 9 months. Further it will be needed only during one phase of construction. Thus, an adjustment factor is not needed, and the final quantity for this item is 150 LF.

Item Number 209-05, Sediment Removal, per CY

Sediment Removal is paid for per project and is thus not described in detail here.

10.08.2.5 ENHANCED SILT FENCE (EC-STR-3D)

Enhanced Silt Fence
Reference: SR-840, Williamson Co., TN (2004)

10.08.2.5.1 DEFINITION AND PURPOSE

Enhanced silt fence consists of a woven monofilament geotextile fabric reinforced with a metal wire backing mounted on metal posts which are driven 3.5 feet into the ground and placed at 2 foot centers. This measure serves to capture suspended sediments from stormwater flow via settling (the primary mechanism) and flow-through filtration (the secondary mechanism). It is usually used on a temporary basis to prevent erosion on the surface of a swale, ditch, or other conveyance by reducing the stormwater flow velocity.

Due to its frequent application in concentrated flow environments, the geotextile fabric in the fence offers increased strength and durability properties in order to withstand both the pressure and impingement forces imposed by flowing water. Based on ASTM standards, silt fence fabrics are rated based upon their tensile, burst and puncture strengths. For all three factors, the geotextile fabric used in enhanced silt fence offers strengths at least 200% greater than what can be provided by standard woven slit-film silt fence fabric. In addition, the geotextile fabric used in enhanced silt fence offers vastly improved hydraulic properties as compared standard woven slit-film fabrics. The enhanced silt fence fabric offers water flux rates over 800% greater than those offered by standard woven slit-film silt fence fabrics, while maintaining equal or, in some cases, finer apparent opening sizes. Thus, the enhanced silt fence fabrics can offer greater flow-through rates without sacrificing the overall filtration efficiency of the measure compared to standard woven slit-film silt fence fabric.

As a structural system, enhanced silt fence has been designed for high flow applications and the associated stresses encountered under such conditions. Field observations have confirmed the durability of this measure, even when it has been overtopped.

10.08.2.5.2 APPROPRIATE APPLICATIONS

This measure is applied primarily to construct ditch checks in small open channels conveying stormwater flow, as described in Section 10.08.1.1. However, it may also be applied on graded areas, in place of silt fence, where large sheet flows are expected or where other small localized erosion and resulting sedimentation problems exist. Enhanced silt fence should not be used to replace silt fence with wire backing.

This measure should not be used in any waterways designated as ephemeral, intermittent, or perennial streams.

10.08.2.5.3 LIMITATIONS

This effectiveness of this BMP may be reduced when the fence is bypassed or overtopped during heavy rain events.

This measure shall not be used in or adjacent to streams, wetlands, ponds, springs, or any other natural water resource.

10.08.2.5.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is not required; however, when enhanced silt fence is specified, the following standards should be used.

Enhanced silt fence should be installed according to the details and specifications shown on EC-STR-3D and EC-STR-3E in order to ensure that it will achieve its required structural capabilities.

It is important to install the fence in a manner which will prevent unwanted bypassing of flow around the ends of the structure in high flow conditions.

When applied on graded areas, enhanced silt fence should be installed on the contour in order to ensure that concentrated flows will not occur due to an overflow at a single point. Where this is unavoidable, machined riprap Class A-1 should be installed as appropriate on the downstream side of the fence in order to provide armoring at points where the fence may be overtopped. The upper surface of this riprap should be flush with the ground surface in order to avoid interfering with the filtration capability of the fence.

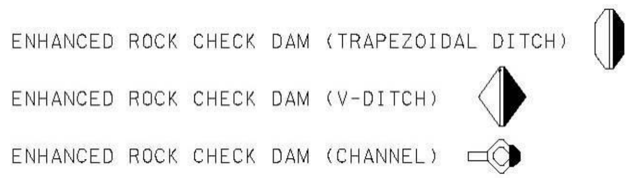
Enhanced silt fence shall be paid for under the following item numbers:

- 209-05, Sediment Removal, per CY
- 209-08.04, Temporary Enhanced Silt Fence, per LF

10.08.2.5.5 EXAMPLE APPLICATION

An example of applying this measure in a ditch is provided in Section 10.08.1.1.

10.08.2.6 ENHANCED ROCK CHECK DAM (EC-STR-6A)



Enhanced Rock Check Dams
Location: SR-24, Davidson County, TN (2007)

10.08.2.6.1 DEFINITION AND PURPOSE

An enhanced rock check dam is similar to a rock check dam (see EC-STR-6) except that it includes a layer of mineral aggregate (size 57) on the upstream side which is separated from the riprap structure by two layers of geotextile fabric. Enhanced rock check dams can serve the same purpose as rock check dams in that they act to reduce flow velocity in a ditch or stream, allowing sediments in the runoff to settle prior to leaving the site. However, the smaller aggregate and filter fabric in enhanced rock check dams may also provide a filtration capacity, when it is not overtopped, increasing the ability of the measure to remove sediments from stormwater flow.

10.08.2.6.2 APPROPRIATE APPLICATIONS

Enhanced rock check dams may be used in roadside ditches, as well as in waterways which have defined channels. This measure is often installed at the ultimate outfall point (or “critical point” as defined in Section 10.08.1.1) for runoff from a project, and is thus the last line of defense against pollution caused by the release of sediments from a construction site. They should therefore be used in conjunction with other on-site measures, such as silt fence, catch basin filters, slope drains, etc. Enhanced rock check dams are also used with sediment traps.

Since the maximum drainage area for an enhanced rock check dam can be as great as 30 acres, they may be applied in situations where the drainage area exceeds the maximum for measures such as rock check dams and enhanced silt fence. For sites which drain to Exceptional Tennessee Waters or sediment-impaired streams, the maximum allowable drainage area shall be 20 acres.

10.08.2.6.3 LIMITATIONS

Enhanced rock check dams should not be used in streams or wetlands unless provided for in the permits. The use of this device in waterways will likely require an Aquatic Resources Alteration Permit (ARAP) from the Tennessee Department of Environment and Conservation and possibly a Section 404 permit from the U.S. Army Corps of Engineers.

10.08.2.6.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is not required when the drainage area for the enhanced rock check dam is less than 20 acres. When the drainage area for the enhanced rock check dam is greater than 20 acres formal design is required. Enhanced rock check dams should be shown in the EPSC plans based on EC-STR-6A, supplemented with the following criteria. When enhanced rock check dams are used with a drainage area of 20 acres or more the structure height, weir height, weir width, and spacing should be labeled for each one used in the EPSC plans.

Enhanced rock check dams may be applied at sites with drainage areas up to 20 acres. However, where the Environmental Division has determined that a site does not drain to listed Exceptional Tennessee Waters or a sediment-impaired stream, the allowable drainage area may be increased to 30 acres.

When used in a roadway side ditch or channel, an enhanced rock check dam should be provided with a center overflow weir 1 or 2 feet below the elevation of the structure at the edges, respectively. This weir is necessary to ensure that overflows will be concentrated at the center of the ditch instead of at the sides, where they could cause the enhanced rock check dam to be washed out.

Enhanced rock check dams should be placed on geotextile fabric (Type III) as described in the Standard Drawing. This geotextile fabric is necessary to prevent the piping of channel bed materials through the rock structure and thus reduce the possibility of undermining. Also, the geotextile fabric should be arranged so that there will be two layers on the slope between the riprap and the mineral aggregate (size 57). This will increase the capacity of the structure to act as a filter, when it is not overtopped.

The geotextile fabric used for enhanced rock check dams in roadside ditches should be extended an additional 3 feet downstream from the toe of the riprap structure. This will help to prevent erosion which might be caused by flows over the overflow weir.

Geotextile fabric (Type III) shall meet the requirements of the standard specification for geotextile AASHTO designation M-288, Erosion Control.

When an enhanced rock check dam is used in a roadside ditch, the overflow weir should be as high as possible, within the limits set by the standard drawing, in order to maximize the filtration capacity of the structure. Thus, whenever possible, the overflow weir should be set a height 1 foot below the top of the ditch banks, so that the overall height of the structure will be equal to the ditch banks. However, where the drainage area at the site exceeds 20 acres, the designer should check the depth of flow over the weir for the design discharge by using the weir equation as presented in Chapter 8. The depth of the flow over the weir (H in the weir equation) might exceed 1 foot for these larger drainage areas, thus requiring an adjustment in the weir height so that the structure will not be overtopped at the design flow. For such cases, the height of the overflow weir should be based on the flow depth at the peak discharge generated by the storm event specified in Section 10.05.1. On the other hand, where the depth of the roadside ditch is less than 2.5 feet, the designer should consider using another measure such as enhanced silt fence check, since it will not be possible to provide the minimum weir height of 1.5 feet.

The detail shown on the Standard Drawing for enhanced rock check dams in channels would typically be applied in a larger waterway which has a defined channel and over-banks. It is suited for this application in that:

- The width of the overflow weir is to be a minimum of two thirds of the channel bottom width. This will direct the main force of any overflows toward the center of the channel so that the potential for erosion on the sides of the channel will be reduced.
- A riprap apron is provided on the channel bottom to prevent the erosion of the channel bottom. This is required because of the generally larger flows which could occur over the weir.
- The minimum distance between the top of the structure and the level of the overflow weir is 2 feet, which allows the structure to accommodate larger overflows.

As with enhanced rock check dams in roadside ditches, the weir for an enhanced rock check dam in a channel should be as high as possible in order to maximize the filtration capacity of the structure. Typically, this will be accomplished by setting the weir at a level 2 feet below the sides of the structure as described above. Because the drainage area is usually limited to 20 acres, it is unlikely that the weir flow depth will exceed 2 feet for the design discharge; thus, analysis of the structure with the weir equation will be up to the discretion of the designer.

Where multiple enhanced rock check dams are being used in a waterway, the spacing between the structures may be determined based on the graph titled “Rock Check Dam Spacing” on Standard Drawing EC-STR-6. As indicated in that drawing, the spacing between the structures should be based on the height of the overflow weir, not the total height of the structure. In addition, the spacing indicated is from the upstream edge of the overflow weir to the downstream toe of the next structure above.

Under certain circumstances, enhanced rock check dams may remain in place as a permanent ditch check at locations where removal would be difficult and might cause significant disturbance. If known during EPSC plan preparation, the designer should indicate on the plans which (if any) should remain in place.

Enhanced rock check dams shall be paid for under the following Item Numbers:

- 209-05, Sediment Removal, per CY
- 209-08.08, Enhanced Rock Check Dam, per Each

The computation of quantities for enhanced rock check dams is somewhat complicated due to the comparatively complex geometric shapes of the riprap structures. Table 10A-8 through 10A-12 in the Appendix may be used to help simplify the determination of quantities for enhanced rock check dams. These tables provide typical quantities for enhanced rock check dams in various roadway side ditch configurations. Thus, quantities for these structures may be determined simply by looking up the appropriate tables. Quantities for enhanced rock check dams in channels will generally be identical to those for enhanced rock check dams in roadway side ditches, except for the riprap apron, which will require some additional quantities for riprap and geotextile fabric. However, because of the rectangular shape of this apron, the additional quantities can be determined easily.

10.08.2.6.5 EXAMPLE APPLICATION

Given: A proposed road reconstruction project is served by a roadside ditch which has a 4-foot bottom width and 6H:1V side slopes. At the upstream end of the ditch, a 30-inch diameter cross drain conveys runoff from portions of the project into the ditch. The ditch extends at a slope of 2% from the outfall of the cross drain for a distance of 200 feet to the end of the project. In addition, the ditch will maintain a consistent cross section 3.0 feet deep.

Find: Calculate the required quantities for enhanced rock check dams in this roadside ditch.

Solution:

Step 1: Determine the height of the enhanced rock check dams: Since the ditch is 3.0 feet deep; it is decided to place the overflow structure 2 feet above the bottom of the ditch. This will maximize the capacity of the enhanced rock check dam and maintain the minimum distance of 1 foot between the top of the structure and the overflow weir.

Step 2: Determine the enhanced rock check dam layout: Given a weir height of 2.0 feet and a stream slope of 2.0%, the graph “Rock Check Dam Spacing” is used to determine that the enhanced rock check dams should be spaced at an interval of 100 feet. Thus, two enhanced rock check dams will be required in the ditch, one at a distance of 100 feet from the cross drain outlet and the other 200 feet downstream from the outlet, at the end of the project.

Step 3: Determine the quantities: The pay items for these enhanced rock check dams are:

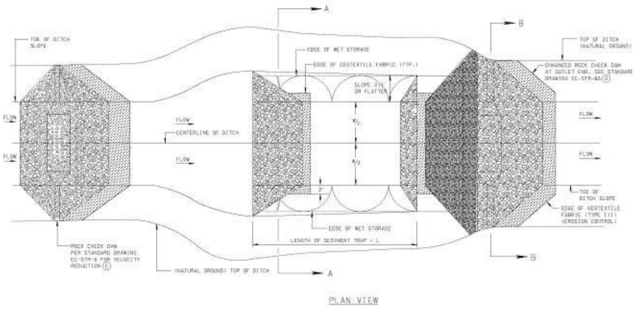
Item Number 209-05, Sediment Removal, per CY

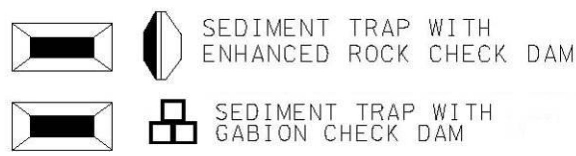
For additional details on computing Item 209-05, Sediment Removal, refer to Section 10.04.6.2.

Item Number 209-08.08, Enhanced Rock Check Dam, per Each

The final quantity for this item will be 2.

10.08.2.7 SEDIMENT TRAP WITH CHECK DAM (EC-STR-7)





Sediment Trap with
Enhanced Rock Check Dam

10.08.2.7.1 DEFINITION AND PURPOSE

A sediment trap is a small temporary basin excavated into a ditch. It is used in combination with a rock check dam and an enhanced rock check dam or gabion check dam. The purpose of a sediment trap with a check dam is to detain sediment laden stormwater runoff from small disturbed areas so that sediment can settle out.

10.08.2.7.2 APPROPRIATE APPLICATIONS

Sediment traps should be used in ditches downstream of disturbed areas no more than 3 acres in size. They should be used when high sediment loads are expected and additional storage is needed behind an enhanced rock check dam.

10.08.2.7.3 LIMITATIONS

Sediment traps with check dams should not be used in perennial streams, wetlands, or in waterways where the channel bottom is comprised of exposed rock. Sediment traps usually remove only coarse to medium-sized sediment particles and may thus require additional sediment control measures. In addition, they may require relatively frequent inspection and maintenance.

10.08.2.7.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is required in that the hydrologic and hydraulic analysis of the ditch is necessary in order to determine the dimensions of the sediment trap. For each sediment trap the length (L), width (W), depth (D1), and height of the enhanced rock check dam (D2) should be provided in the EPSC plans.

The drainage area for a sediment trap with a check dam should be 3 acres or less. Where the drainage area is greater than 3 acres, the designer should consider the use of a Sediment Basin (see 10.08.2.12).

The inlet and outlet of a sediment trap should be provided with riprap slopes as shown in Standard Drawing EC-STR-7.

The rock check dam and enhanced rock check dam or gabion check dam which are to be built in conjunction with a sediment trap should be designed based on the guidelines provided in Sections 10.08.1.2, 10.08.2.6, and 10.08.1.13.

A sediment trap should be provided with a total storage volume of 134 cubic yards (3618 cubic feet) per acre of drainage area. Half of this storage volume should be in the form of a permanent pool excavated below the existing ditch bottom. This is termed the wet storage volume and it provides a space where the trapped sediments can accumulate.

The remaining half of the storage above the permanent pool is termed the dry storage. Runoff detained within this volume during larger storm events will be drawn down slowly as it filters through the enhanced rock check dam or gabion check dam. This allows an extended period of time for sediments to settle out.

The volume provided in the wet storage of a sediment trap may be determined by use of Figure 10SC-2. This graph reflects the sediment trap geometry shown in Standard Drawing EC-STR-7, based on the assumption that the excavated basin will be horizontal. For most stream slopes, the error introduced by this assumption will be negligible. The dimension D_1 noted on the graph represents the depth of the wet storage volume, measured from the low point of the excavated area at the base of the outlet riprap to the natural ditch bottom elevation at the downstream end of the trap. The maximum depth of the excavated area is 4 feet.

The dry storage is measured from the top of the wet storage to the crest elevation of the overflow weir provided on the enhanced rock check dam or gabion check dam downstream of the basin. The volume provided in the dry storage area may be computed as:

$$V_2 = \frac{A_1 + A_2}{2} \times D_2$$

Where: V_2 = the dry storage volume, (ft^3)
A_1 = the surface area at the top of the wet storage, (ft^2)
A_2 = the surface area at the top of the dry storage, (ft^2)
D_2 = the dry storage depth, measured as described above, (ft)

The Example Application provides a detailed procedure for determining A_2, and thus the volume available in the dry storage area.

Sediment traps with check dam shall be paid for under the following item numbers:

- 209-05, Sediment Removal, per CY
- 209-10.20, Temporary Sediment Trap, per CY

Rock check dams, enhanced rock check dams, and gabion check dams shall be paid for according to their respective standard drawing.

The quantity for the sediment trap is calculated based on only the volume excavated for the wet storage below the grade of the ditch bottom. Riprap or other materials used to form the sediment trap are nonetheless included in this bid item. Quantities for the enhanced rock check dam, gabion check dam, and rock check dam should be computed separately, as described in their respective sections.

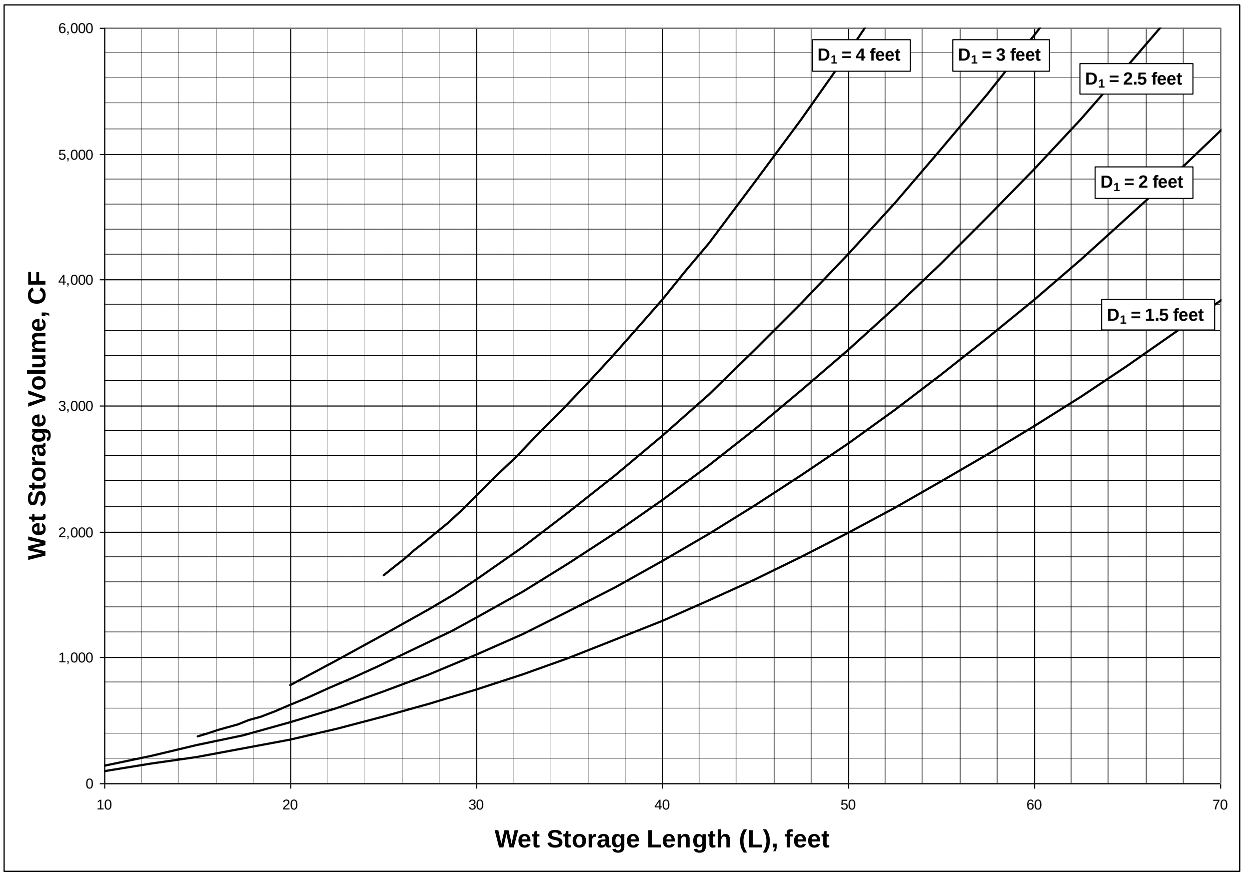


Figure 10SC-2
Wet Storage Volume for a Sediment Trap Designed According to EC-STR-7

It is important to take into account the duration of a project when calculating quantities for sediment traps. The expected life span of this measure is usually no longer than 24 months. Therefore, projects of long duration may require a complete replacement of the sediment trap with check dam. The quantity for a sediment trap which is to be in place for a long period of time should be based on the assumption that it will be replaced every 2 years, on the average. The staging of the Erosion Prevention and Sediment Control plan should be considered in computing this quantity, as well as the contractor's phasing plan, when it is known. The computations would thus take the following form:

$$\frac{Calendar\ Days\left(accounting\ \ for\ EPSC\ Plan\ Phases\right)}{\left(24\, months\right)\times\left(30\, days\right)}=Adjustment\ \ factor$$

The adjustment factor should be rounded to nearest whole number. The final quantity may then be computed from:

$$Computed\ Volume\ of\ \ Sediment\ trap\times Adjustment\ \ Factor\ =Total\ Quantity,\left(CY\right)$$

10.08.2.7.5 EXAMPLE APPLICATION

Given: A sediment trap with enhanced rock check dam is being designed for a project. The ditch at the sediment trap location has the following characteristics:

- drainage area = 2.5 acres
- stream slope = 1.7%
- channel bottom width = 6 feet
- channel side slopes = 4H:1V

The sediment trap is proposed to be in place for the entire duration of the project, which is expected to be 42 months.

Find: Develop a design for the sediment trap and calculate the required quantities.

Solution:

Step 1: Determine the required storage volume: As described in the Planning and Design Criteria, a sediment trap should offer a volume equal to 3618 cubic feet per acre of drainage area, half of which is to be in the wet storage area. Thus, the total storage to be provided is computed as:

$$2.5\, acres\times\frac{3618\, CF}{acre}=9045\ \text{CF}$$

The volume of wet storage is half of this volume, or 4522.5 CF

Step 2: Determine the dimensions of the wet storage area: To determine the length of the wet storage area, L, a horizontal line corresponding to 4522.5 CF of storage is projected from the Y-axis of Figure 10SC-2. Inspection of the graph shows that the basin could be from 44 to 65 feet long, depending on the desired depth of wet storage, D_1. Based on the conditions of the site, it is decided that the basin can be constructed along a section of the roadway side ditch. This allows a trade-off between the depth of the basin and its length, and basin length is determined to be 44 feet so that the maximum wet storage depth of 4 feet can be utilized. The width of the basin floor is to be half of the length at the top of the basin so it will be 22 feet wide. The side slopes of the wet storage are 2H:1V, thus, the top width of the wet storage may be computed as:

$$Topwidth=W+2zD_1=22+\left(2\right)\left(2\right)\left(4.0\right)=38\ \text{feet}$$

Where: W = width of the sediment trap floor, (ft)
z = side slopes of the sediment trap, zH:1V
D_1 = depth of the wet storage area, (ft)

The surface area at the top of the wet storage, A_1, is then computed as:

$$A_1 = Topwidth \times L = 38 \times 44 = 1672 \text{ SF}$$

Step 3: Determine the height of the enhanced rock check dam: The storage volume offered by the dry storage area is determined by D_2, the height of the enhanced rock check dam spillway above the top of the wet storage. As indicated in the Planning and Design Criteria, the dry storage volume is computed as the average of A_1 and A_2, multiplied by D_2. A_1 has been determined in the previous step. Thus, designing the dry storage area involves determining a spillway height such that the resulting value of A_2 will produce a dry storage volume which is approximately half of the total required storage volume. Due to the number of variables, finding the spillway height is a trail-and-error process as follows:

A. Compute the minimum possible value of D_2: During periods of high flow, water will collect in the dry storage area until it spills over the weir provided on the enhanced rock check dam. Inspection of Standard Drawing EC-STR-7 will indicate that the resulting pool of water must be sufficiently long to extend past the end of the wet storage area. Since there is to be an additional 2 feet between the top of the wet storage and the toe of the enhanced rock check dam, the minimum possible value of D_2 can be computed as:

$$D_2 \geq (L+2) \times S_0 \geq (44+2) \times 0.017 = 0.78 \text{ feet}$$

Where: D_2 = height of the enhanced rock check dam weir above the wet storage, (ft)
L = length across the top of the wet storage, (ft)
S_0 = slope of the stream bed, (ft/ft)

This computed value of D_2 is less than the minimum check dam height specified on the standard drawing. Thus, a minimum value for D_2 of 1.5 feet will be used in the following computations.

B. Assume a trial value for D_2: For the initial trial, the minimum value of D_2 will be used to determine A_2. If the dry storage volume resulting from this value of D_2 is greater than required, no further computations will be required. Otherwise, D_2 will be increased until the proper storage volume is obtained.

C. Compute the ditch top width adjacent to the wet storage: To simplify the computation of A_2, the pool area at the top of the dry storage is divided into two sections. The first section is a rectangle which extends from the toe of the enhanced rock check dam to the upstream end of the wet storage. This is based on the assumption that the sediment trap is horizontal across this length, which may not be true. However, the error introduced by this assumption is considered to be negligible. The second section of the pool is a trapezoid which extends from the upstream end of the wet storage to the point at which the pool intersects the ditch bottom. This portion of the pool will be discussed in later steps.

The top width of the pool at the top of the dry storage, W_T, will be equal to the top width of the wet storage plus D_2 times the side slopes of the ditch. Thus:

$$W_T = [W + 2zD_1] + 2z_d D_2 = [22 + (2)(2)4] + (2)(4)1.5 = 50.0 \text{ feet}$$

Where: W_T = top width at the top of the dry pool, (ft)
W = width of the floor of the sediment trap, (ft)
z = sediment trap side slopes, (zV:1H)
D_1 = depth of the wet storage area, (ft)
z_d = side slope of the ditch channel walls
D_2 = depth from the top of the wet storage to the top of the dry storage, (ft)

D. Compute the length of the dry storage pool upstream of the wet storage area: As discussed in the previous step, the second portion of A_2 consists of a trapezoid which extends from the upstream end of the wet storage area to the point where the dry storage pool intersects the ditch bottom. Since the total length of the dry storage pool is D_2 divided by the slope of the stream, and the length of the rectangular portion of the pool is the length of the wet storage, L, plus 2 feet, the length of the trapezoidal area, L_u, may be computed as:

$$L_u = \frac{D_2}{S_o} - (L + 2) = \frac{1.5}{.017} - (44 + 2) = 42.2 \text{ feet}$$

Where: L_u, D_2, and S_o are defined above.

E. Compute A_2: To compute the water surface area at the top of the dry storage pool, the areas of the two portions analyzed above are computed and added together. It is assumed that the width of one end of the trapezoidal area is equal to W_T, and the width of the other end is equal to the channel bottom width, BW. Thus:

$$A_2 = (L + 2)(W_T) + \left(\frac{BW + W_T}{2}\right)(L_u) = (44 + 2)(44.2) + \left(\frac{6 + 44.2}{2}\right)(1.5) = 3482.6 \text{ SF}$$

F. Compute the dry storage volume, V_2: Using Equation 10SC-1, the dry storage volume may be computed as:

$$V_2 = \left(\frac{A_{1+} A_2}{2}\right)(D_2) = \left(\frac{1672 + 2033}{2}\right)(1.5) = 3866 \text{ CF}$$

G. Adjust D_2 as needed: Since the minimum value of D_2 has resulted in a storage volume less than the required 4522.5 CF, it will be necessary to increase the trial depth and return to Step C, above. The successive trials are summarized in Table 10SC-2:

Trial D_2 (feet)	**W_t (feet)**	**L_u (feet)**	**A_2 (SF)**	**V_2 (CF)**	**Result**
1.5	50.0	42.2	3482.6	3866	Too low
1.6	50.8	48.1	3703.3	4300	Too low
1.65	51.2	51.1	3815.5	4527	Closest
1.7	51.6	54.0	3928.8	4761	Too high

Table 10SC-2
Summary of Computations for the Dry Storage Depth

Since an enhanced rock check dam overflow height of 1.65 feet yielded a dry storage volume which was the closest to the target value of 4522.5 CF, it is rounded to 1.7 feet and selected as the design value. It should be noted that since the length of the wet storage volume, L, equals 44 feet, and the dry storage length upstream of the wet storage, L_u, is approximately 51 feet. Thus, the distance between the upstream toe of the rock silt screen and the toe of the rock check dam should be a total of 97 feet, including 2 feet between the wet storage volume and the upstream toe of the enhanced rock check dam, as shown in the standard drawing.

Step 4: Determine the quantities: The pay items for this measure are:

Item Number 209-10.20, Temporary Sediment Trap, per CY

The quantity for this item should be based on the required wet storage volume, which was computed above. However, since the expected project duration will be longer than the average life expectancy for a sediment trap, the quantity must be adjusted by a factor determined as follows:

$$\frac{42\ months}{24\ months} = 1.75 \approx 2$$

Thus, the final quantity will be the wet storage total volume times the multiplier:

$$4522.5\ CF \times 2 = 9045\ CF \times \frac{1\ CY}{27\ CF} = 335.0\ \text{CY}$$

Item Number 209-05, Sediment Removal, per CY

Sediment Removal is paid for per project and is thus not described in detail here.

10.08.2.8 FILTER SOCK (EC-STR-8)

Filter Socks in Ditch Application
Reference: Filtrexx International, LLC

❋❋SOCK❋❋SOCK❋❋SOCK FILTER SOCK

10.08.2.8.1 DEFINITION AND PURPOSE

Filter socks consist of flexible mesh tubes, filled with some type of filtration media. Usually, this media will be composed of either wood chips (mulch) or a 50/50 combination of wood chips and compost material. Compost can be derived from a variety of materials (called “feedstocks”) and is a manufactured product which is goes through a specific heating process. This process accelerates the decomposition of the feedstock, destroys weed seeds and bacteria, and reduces the attractiveness of the material to insects.

Filter socks differ from sediment tubes (see EC-STR-37) in a variety of ways. One of the most significant differences is that sediment tubes are delivered to the project site completely assembled, while filter socks are produced in the field by means of pneumatic equipment which blows the media into the mesh tube. This allows for greater flexibility in sock length as well as allowing for much longer continuous sections of sock. In certain applications, other types of materials may be used to fill the mesh sock as described in the following sections. Sediment tubes must be 100% biodegradable while filter sock can contain non biodegradable material that must be removed.

Filter socks act primarily as sediment control devices by reducing runoff flow velocities so that eroded sediments can be settled upstream of the filter. They can also filter the runoff as it passes through the material in the sock. As is the case with filter berms, compost materials in the media tend to bind soil particles and other pollutants by means of chemical interaction.

10.08.2.8.2 APPROPRIATE APPLICATIONS

Filter socks may be utilized on slopes or ditches to reduce flow velocities, retain eroded sediments, and capture other pollutants. They may be placed at the top or toe of the slope as well as at regular intervals on a long slope. In addition, they may be placed around area drain inlets.

When installed, filter socks tend not to retain their circular cross-sectional shape; rather, the sock will normally flatten into an oval. This increases the area of ground contact, eliminating the need for trenching. Thus, filter socks may be useful on paved or rocky areas where trenching would be difficult. However, stakes usually cannot be driven in such areas, and filter socks will remain stable only on mild slopes where flows will be moderate.

This measure is generally used in combination with other BMPs such as slope surface roughening, seeding with mulch, etc. Additionally, because the netting, filler material, and stakes can be biodegradable, the need for complete removal may be eliminated. All non biodegradable portions of the filter sock must be removed.

10.08.2.8.3 LIMITATIONS

Like most other linear BMPs, filter socks should be installed along a horizontal contour. Where this is violated, flow will tend to concentrate along the low points on the sock, potentially resulting in erosion downstream of the measure. Because of this, the use of filter socks as perimeter controls should be avoided, unless the perimeter of the site is completely level, or the space required to follow the contour is available.

Filter socks should not be used in areas subject to frequent traffic by construction vehicles. Damage caused by vehicles could allow the sock to rupture and allow the passage of sediment-laden runoff.

This measure may not be used in a natural stream or any ditch with perennial flows.

10.08.2.8.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is not required; however, when filter socks are specified they should be shown in the EPSC plans according to EC-STR-8. At each location filter socks are used their size should be labeled in the EPSC plans.

Filter socks are available in nominal diameters of 8, 12, 18 and 24 inches. Because they are constructed on site, individual segments of filter sock can be up to 250 feet long. Typically, the tubing mesh will be constructed of 5 mil HDPE filaments which are not biodegradable; although, biodegradable tubing material is available.

The minimum specification for filter sock filler material is provided on the standard drawing. This specification provides for somewhat coarser material than would be used in a filter berm (see Section 10.08.2.14), so that particles of the media will not be able to escape through the 3/8th inch openings in the tubing mesh.

Compost or other organic materials used as filtration media should be blown into the sock using appropriate pneumatic equipment. Hand-filling of these materials will not achieve the level of compaction necessary to ensure the effectiveness of the measure.

Compost is a manufactured product which should be acquired from an approved supplier. Thus, the cost of bringing this material to the job site may be a factor at some locations. Wood chips, on the other hand, can be produced on-site as a byproduct of site clearing activities. The choice of measure (filter sock, filter berm, silt fence, etc.) to be applied at a given site should be based on the availability and relative costs of the required materials.

Filter socks should be placed on properly prepared surfaces. In general, the surface should be even, free of large rocks or other surface irregularities and be cleared of large vegetation such as brush or tall grasses. This is essential to maintain good ground contact in order to prevent any leakage under the sock. Additional mulch or compost can be placed along the upstream face of the sock in order to provide extra protection from this leakage.

Stakes used to install filter socks should not penetrate the tubing mesh as this will cause damage which would allow the filler material to leak out, resulting in the failure of the measure. Stakes should be placed on the downstream face of the sock, inclined toward the flow direction. At locations where a sturdier installation is desired, the mesh tube can be secured to the stakes by means of zip ties or twine.

The drainage area upstream of a filter sock on a slope should be no greater than ¼ acre per 100 linear feet of sock.

Filter socks should be applied at the top of a slope which receives runoff from areas above the slope. A sock should also be placed at the base of a slope, about 10 feet away from the toe in order to provide an area for the storage of sediments. On long slopes where the drainage area limit given above would be exceeded, one or more additional rows of filter sock should be placed, spaced as recommended in the table “Filter Sock Spacing for Slope Application” on the standard drawing. Sock spacing using the values on this table will ensure that the drainage area limitation is met.

Both ends of a run of filter sock should be turned up-slope and extended to a point where the ground is higher than the top of the sock at its lowest point. This will prevent erosion which could occur if flow were to bypass around the ends of the measure.

Where long continuous rows are required on a slope, the ends of the individual segments of sock should be joined as shown on the standard drawing. This will ensure that gaps will not occur between the individual segments, allowing sediment-laden water to escape.

In most cases, filter sock on slopes should be removed when permanent vegetation is fully developed or when any other form of permanent erosion protection is in place. Removal may be accomplished by cutting the sock open and spreading the fill material on the site. All non biodegradable materials shall be removed. The tubing mesh would then typically be removed, unless it is composed of biodegradable material. In such cases, it would be allowable to leave the tubing mesh on the site to decompose.

Filter socks used in a ditch should extend on the sides of the ditch to a height equal to 3 feet plus the installed height of the sock, or to the top of the ditch, whichever is less. This will ensure that the ends of the sock will not be overtopped during the design storm event, causing erosion due to bypass flows.

The minimum nominal diameter for a single filter sock applied in a ditch should be 24 inches, which corresponds to a 19-inch installed height. The required height may also be achieved by stacking smaller diameter socks as shown on the standard drawing. This will ensure that the sock will function effectively as a velocity control device, allowing sediment to drop out of the flow. A clean filter sock in a ditch application will typically have a flow-through capacity smaller than the design discharge. Thus, its primary benefit will be as a velocity control device as filtration will be provided only for smaller flows. The spacing between filter socks should be based on the table “Filter Sock Spacing for Ditch Application” on the standard drawing.

At sites which drain to Exceptional Tennessee Waters or sediment-impaired streams, the maximum drainage area for a filter sock in a ditch application should be no more than 10 acres. At other sites, the maximum drainage area may be increased to 15 acres.

Filter socks applied in ditches shall be completely removed once they are no longer needed.

Filter socks shall be paid for under the following item numbers:

- 209-03.20, Filter Sock (8 inch), per LF
- 209-03.21, Filter Sock (12 inch), per LF
- 209-03.22, Filter Sock (18 inch), per LF
- 209-03.23, Filter Sock (24 inch), per LF
- 209-05, Sediment Removal, per CY
- 209-08.09, Filter Sock Check Dam, per Each

The materials used in filter socks may have a design life of one year or more. However, this material may become clogged with sediment in a much shorter time frame and may fail, requiring replacement. Thus, it may be necessary to consider a shorter life span when calculating quantities for a long-duration project. The length of time required to completely clog a filter sock may vary widely, depending on rainfall, the diameter and spacing of the socks, the type of filler material and the types of sediment on the site. In the absence of more detailed information, it should be assumed that filter socks a life span of 6 months when properly maintained after rainfall events. Projects exceeding this duration may require a complete replacement and re-measurement of the material. In addition, the staging of the Erosion Prevention and Sediment Control plan should be considered in computing the quantity. The computations would take the following form:

$$\frac{Calendar\ Days\left(accounting\ \ for\ EPSC\ Plan\ Phases\right)}{\left(Life\ span\ in\ months\right)\times\left(30\ days\right)} = Adjustment\ \ factor$$

The adjustment factor should be rounded to nearest whole number. The final quantity may then be computed from:

$$Computed\ Linear\ Feet\ of\ \ Filter\ Sock \times Adjustment\ Factor = Total\ Quantity,\ LF$$

10.08.2.8.5 EXAMPLE APPLICATION

Given: A new ramp is to be constructed for a portion of a roadway relocation project. The embankment for this ramp is to be 400 feet long and 15 feet high. The upper portion of the ramp will consist of a 25-foot wide clear zone at a 6H:1V slope, and the remainder will be at a 4H:1V slope. The ramp is expected to require four months for construction. It has been decided to use filter socks to provide sediment control at this site.

Find: Determine the filter sock layout to be used at this site as well as the required quantities.

Solution:

Step 1: Determine the filter sock layout: As described above, the proposed embankment will have two slope segments, and the filter sock layout will be determined beginning from the top. To begin with, an 8-inch diameter filter sock will be placed at the top of the slope to intercept any sediment eroded from the roadbed during construction. The next row of filter sock will be placed at the break in grade between the clear zone and the 4H:1V slope. The clear zone will be 25 feet wide at 6H:1V slope; thus, based on the table "Filter Sock Spacing for Slope Application" on the standard drawing, an 18-inch diameter filter sock will be used at the break in grade.

The 6H:1V slope of the clear zone accounts for approximately 4.2 feet of the total embankment height of 15 feet. Thus, the 4H:1V slope accounts for the remaining 10.8 feet, and the bottom width of this portion of the embankment will be four times the height, or 43.2 feet. Thus, the total slope length from the break in grade to the toe of slope will be:

$$\sqrt{10.8^2 + 43.2^2} = 44.5 \text{ feet}$$

Because the last row of filter sock is to be placed 10 feet away from the toe of slope, the total length to be protected is approximately 55 feet. Based on the spacing table on the standard drawing, this length could be protected by two rows of 18-inch filter sock spaced at about 28 feet on center, or by three rows of 12-inch filter sock spaced at about 18 feet on center. Based on cost information provided by a product vendor, it appears that two rows of 18-inch filter sock can be installed at a somewhat lower price, and this option is selected for the site.

Step 2: Compute the required quantities: The pay item for this measure is:

Item Number 209-03.20, Filter Sock (8 inch), per LF

As discussed above, one row of 8 inch filter sock will be used at the top of slope. The final quantity for this item will be 400 ft.

Item Number 209-03.22, Filter Sock (18 inch), per LF

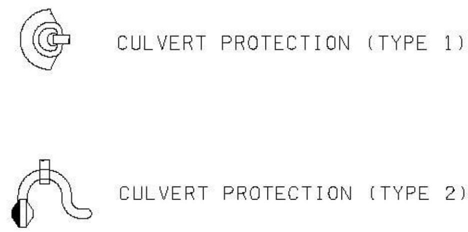
As discussed above, three rows of 18 inch filter sock will be used. The final quantity for this item will be 1200 ft.

Item Number 209-05, Sediment Removal, per CY

For additional details on computing Item 209-05, Sediment Removal, refer to Section 10.04.6.2.

10.08.2.9 CULVERT PROTECTION (EC-STR-11 AND 11A)

Installation of Culvert
Protection Type 1
Location: SR-385, Memphis, TN (2005)



10.08.2.9.1 DEFINITION AND PURPOSE

Culvert Protection Type 1 is somewhat similar to an enhanced rock check dam in that it usually consists of a riprap structure with geotextile fabric (Type III) and a layer of mineral aggregate (size 57) placed on the upstream side. This type of culvert protection acts in a manner similar to enhanced rock check dams in that it can reduce flow velocity in a shallow ditch or swale, allowing sediments in the runoff to settle prior to entering a cross or side drain. Further, the smaller aggregate and filter fabric in the culvert protection provide an additional filtration capacity for low flows which do not overtop the structure, increasing the overall ability of the measure to remove sediments from stormwater flow. Because culvert protection Type 1 consists of a complete ring around the culvert inlet, it serves to reduce the sediment load in all of the flows which enter it.

Culvert Protection Type 2 consists of an open “horseshoe” composed of mineral aggregate (size 57), though other types of materials may be used. This type of protection serves to remove sediments from on-site runoff while allowing run-on flows to pass through unimpeded. In essence, Culvert Protection Type 2 serves to isolate sediment-laden project runoff from run-on flows which are not affected by the project. Culvert Protection Type 2 can be used at the inlet or outlet of a culvert.

10.08.2.9.2 APPROPRIATE APPLICATIONS

In general, Culvert Protection Type 1 is used at the inlet where most of the inflows to the culvert are generated on the project site. Culvert Protection Type 2 is generally applied at the inlet and/or outlet where a significant quantity of run-on flow enters the culvert from off-site areas. The application of Culvert Protection Type 2 assumes that the off-site areas will be undisturbed so that the runoff from those areas will be relatively sediment-free. Culvert Protection Type 1 should still be used at sites where it is anticipated that run-on flows will carry a significant quantity of sediment. Culvert Protection Type 2 should be applied at side drain inlets as shown on the standard drawing.

Culvert Protection Type 1 is often applied at the ultimate outfall point (or "critical point" as defined in Section 10.08.1.1) for runoff from a project, and is thus the last line of defense against pollution caused by the release of sediments from a construction site. It should therefore be used in conjunction with other on-site measures, such as silt fence, catch basin filters, slope drains, etc.

Culvert Protection Type 1 may be used for drainage areas up to 20 acres, but in some cases, may be applied for drainage areas as great as 30 acres. This limit applies to the total area draining to the cross or side drain. The largest pipe size which may be accommodated by Culvert Protection Type 1 is 36 inches. Culvert Protection Type 2 is not specifically limited with regard to culvert size, and may be applied to any size of structure including a box bridge. The allowable drainage area for Culvert Protection Type 2 will depend on the actual BMP (rock berm, silt fence, etc.) being used. If a rock berm is used, the drainage area should be no more than ½ acre per 100 lineal feet of berm. The drainage area limitations of the other possible BMPs are described in the applicable sections of this Manual. The drainage area for Culvert Protection Type 2 is determined based on-site runoff only. The drainage area associated with off-site flow passed through the culvert is not considered.

10.08.2.9.3 LIMITATIONS

Culvert Protection Type 1 shall only be used on the inlet of a culvert. Culvert Protection Type 1 shall not be used in streams or other natural water resources. It should also not be placed in ditches, swales, or other depressions with a depth greater than 1 foot.

10.08.2.9.4 PLANNING AND DESIGN CRITERIA

Formal design will usually not be required. The determination of the dimensions of culvert protection should be based on Standard Drawings EC-STR-11 and EC-STR-11A, supplemented with the following criteria:

The use of Culvert Protection Type 1 is limited to pipes up to 36 inches in diameter. However, Culvert Protection Type 2 may be applied to any size of culvert, including box bridges. Culvert protection may also be applied around any type of endwall, including box bridge wingwalls. Culvert protection may be applied both before and after the endwalls have been constructed.

Culvert Protection Type 1 may be applied at sites with drainage areas up to 30 acres. However, where the Environmental Division has determined that a site drains to Exceptional Tennessee Waters or a sediment-impaired stream, the maximum allowable drainage area shall be 20 acres. As described in the "Appropriate Applications" section, the drainage area is assessed differently for Culvert Protection Type 1 and Type 2.

Culvert Protection Type 1 should be placed on geotextile fabric (Type III) as described in the standard drawings. This geotextile fabric is necessary to prevent the piping of channel bed materials through the rock structure and thus reduce the possibility of undermining. The geotextile fabric should be arranged so that there will be two layers between the riprap and the mineral aggregate (size 57). This will increase the capacity of the structure to act as a filter when it is not over topped.

Geotextile fabric (Type III) shall meet the requirements of the standard specification for geotextiles, AASHTO designation M-288, Erosion Control.

Culvert Protection Type 1 does not require a specific overflow weir, as the entire structure is used to convey any overflows which may occur.

Normally, Machined Riprap Class A-1 is used to construct Culvert Protection Type 1. However, machined riprap (Class A-3) may be used at sites where a relatively large quantity of sediment may be present in the flow. An example of such a situation would be where no other erosion prevention or sediment control measures can be installed upstream of the pipe inlet. The smaller stone size may allow for additional filtration of sediments. However, it also may not match the stability provided by the larger stone sizes in machined riprap class A-1. Thus, machined riprap Class A-3 may be used for pipes up to 24 inches in diameter only where the drainage area is 3 acres or less, and it may be used for pipes from 24 inches to 36 inches in diameter where the drainage area is 6 acres or less. Machined riprap (Class A-3) may not be used in culvert protection Type 2.

Culvert Protection Type 2 typically will wrap around the end of the culvert endwall and extend out to the limits of the disturbed area. If the project includes a roadway side ditch, the protection will either extend across the ditch or connect to an enhanced rock check dam (see EC-STR-6A). If a sediment trap with check dam per EC-STR-7 is proposed for the side ditch, then Culvert Protection Type 2 would also be contiguous with the enhanced rock check dam for that BMP. However, mineral aggregate (size 57) should not be used by itself in a ditch and other types of BMP may require stacking, as shown in the standard drawing. At sites where a roadway side ditch is not present, the Culvert Protection Type 2 would still extend to the limits of the disturbed area and overlap the project perimeter controls a minimum of 2 feet, as shown on the standard drawing.

A number of linear sediment control measures are allowed as alternate materials to the mineral aggregate berm for Culvert Protection Type 2. These include:

- Silt Fence (EC-STR-3B)
- Silt Fence with Wire Backing (EC-STR-3C)
- Filter Sock (EC-STR-8)
- Sediment Tube (EC-STR-37)

At sites where a roadway side ditch is present, these alternate materials would be wrapped around the back of the endwall and then be abutted to the enhanced rock check dam in the ditch. The ends of the alternate materials would then be turned to overlap the perimeter controls on the ditch bank, as shown in the standard drawing, in order to prevent any sediment from escaping around the ends of the measure. Two types of alternate material, sediment tubes and filter socks, may be extended across the ditch in place of the enhanced rock check dam. In these cases, they should be stacked as shown on their respective standard drawings, in order to provide the minimum required check dam height. At sites where no side ditch is present, the alternate materials should be extended to the edge of the disturbed area to overlap with the perimeter controls, as described above.

Culvert Protection Type 1 shall be paid for under the following item numbers:

- 203-01, Road & Drainage Excavation (Unclassified), per CY
- 209-05, Sediment Removal, per CY
- 303-10.01, Mineral Aggregate (Size 57), per Ton
- 709-05.05, Machined Rip-Rap (Class A-3), per Ton
- 709-05.06, Machined Rip-Rap (Class A-1), per Ton
- 740-10.03, Geotextile (Type III) (Erosion Control), per SY

Culvert Protection Type 2 shall be paid for under the following item numbers:

- 209-05, Sediment Removal, per CY
- 303-10.01, Mineral Aggregate (Size 57), per Ton
- 740-10.03, Geotextile (Type III) (Erosion Control), per SY

Silt fence, silt fence with wire backing, enhanced rock check dam, sediment trap with check dam, filter sock, and sediment tube shall be paid for under their respective standard drawing.

The computation of quantities for culvert protection is somewhat complicated due to the comparatively complex geometric shapes of the riprap structures. Table 10SC-3 contains typical quantities which may be used when specifying Culvert Protection Type 1. These quantities are based on the assumption that the riprap and mineral aggregate (size 57) will extend onto the roadway side slope. In addition, the machined riprap quantities include the stone which would be placed on the roadway side slope around the pipe inlet, as shown in the standard drawing.

Item Number	Item Description	Unit of Measure	Quantity	
			15” to 24” Pipe	27” to 36” Pipe
303-10.01	Mineral Aggregate (Size 57)	Ton	4.2	12.4
709-05.06	Machined Rip-Rap (Class A-1)	Ton	22.7	123.2
740-10.03	Geotextile (Type III)	SY	53.8	222.3

Table 10SC-3
Typical Quantities for Culvert Protection Type 1

10.08.2.9.5 EXAMPLE APPLICATION

Given: A cross drain 72 inches in diameter is located within a proposed road reconstruction project for SR-104 in Dyer County. The drainage ditch served by this drain shows up as a “blue line” stream on the quadrangle map. Thus, it is proposed to use culvert protection Type 2 at this site, using mineral aggregate. The project will require the construction of a roadway side ditch extending east from the stream. The side ditch is proposed to have a bottom width of 4 feet, 3H:1V side slopes and an over depth of about 2.5 feet. Due to the topography of the area, a side ditch will not be required along the roadway west of the stream.

Find: Calculate the required quantities for Culvert Protection Type 2 at this site.

Solution:

Step 1: Determine the required length of the culvert protection: Quantities for the Culvert Protection Type 2 will be computed based on the length and cross section of the structure.

A 72-inch pipe requires the use of a Type ‘A’ endwall. Since the proposed culvert protection will wrap around the back of this endwall, it will first be necessary to compute the total length around the outside its face. Based on the standard drawing for this structure, the outside dimension along the back of the endwall will be 7 feet, 10 inches (7.83 feet) and the outside dimension of each leg will be 13 feet, 5 inches (13.42 feet). However, the proposed embankment will have a 3H:1V slope along each leg of the endwall, and it is thus necessary to compute the actual embankment slope length along each leg of the endwall as:

$$Length = \sqrt{13.42^2 + \left(\frac{13.42}{3}\right)^2} = 14.14 \text{ feet}$$

Based on this, the total outside perimeter of the Type ‘A’ endwall is:

$$Perimeter = 7.83 + \left(2 \times 14.14\right) = 36.1 \text{ feet}$$

This result rounded up to a total length of protection of 37 feet around the endwall.

Inspection of the site plans indicates that there is an additional distance of 4 feet from the end of the endwall to the top of bank of the side ditch on the east side of the stream, while the distance from the end of the endwall to the limit of disturbed area on the west side of the stream will be 16 feet. In addition, there will be a minimum of 2 feet overlap between the protection and the site perimeter sediment control measures. Thus, the total length of the gravel berm will be:

$$Length = 37 + 4 + 16 + 2 = 59 \text{ feet}$$

This length will be used to compute the quantity of mineral aggregate in the gravel berm around the endwall.

Step 2: Determine the quantities: The pay items for this culvert protection scheme are:

<u>Item Number 303-10.01, Mineral Aggregate (Size 57), per Ton</u>

Mineral aggregate will be used in this culvert inlet protection scheme for the gravel berm around the endwall. In addition, the gravel berm along the back of the endwall will be perpendicular to the road fill side slope, while it will be parallel to the side slope along the sides of the endwall. Thus, the cross section of the gravel berm will be different in these two areas.

As shown in the standard drawing, the cross section of the gravel berm will have a 1.5H:1V foreslope, a 3H:1V backslope, and a top width of 1.5 feet. Along the sides of the endwall, where the berm is parallel to the road fill slope, it will have a height of 6 inches both on the inside and on the outside of the berm. Thus, the bottom width of the berm will be 3.75 feet, and the cross sectional area may be computed as:

$$Area = 0.5 \times \left(\frac{1.5 + 3.75}{2} \right) = 1.31 \text{ ft}^2$$

Along the back of the endwall, it is necessary to account for the fact that the gravel berm will be perpendicular to the 3H:1V slope of the road fill. The top of the berm will be 0.5 feet above the outside toe. It is found that the total width across the bottom of the berm will be 7.5 feet and that the cross sectional area will be 6.0 ft^2. The length of the berm along the back of the endwall will be approximately 8 feet of the 59-foot total length of the berm. Thus, the volume of gravel in the berm may be computed as:

$$Volume = 8\ feet \times 6.0\ ft^2 + 51\ feet \times 1.31\ ft^2 = 114.8CF \times \frac{1CY}{27CF} = 4.25 \text{ CY}$$

Based on Section 10.04.6, each cubic yard of mineral aggregate (size 57) weighs 1.49 tons. Thus, the 4.25 CY of mineral aggregate is determined to weigh 6.3 tons.

<u>Item Number 740-10.03, Geotextile (Type III), per SY</u>

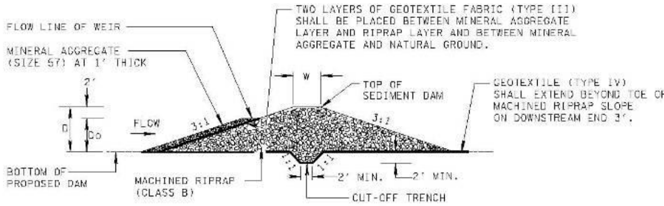
As discussed above, the bottom width of the gravel berm will be 7.5 feet for the 8-foot distance along the back of the endwall, and 3.75 feet for the remaining length. Thus, the total area of geotextile required for the gravel berm will be:

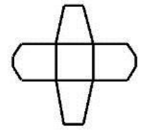
$$Area = (7.5\ feet \times 8\ feet) + (3.75\ feet \times 51\ feet) = 251.3SF \times \frac{1SY}{9SF} = 27.9 \text{ SY}$$

<u>Item Number 209-05, Sediment Removal, per CY</u>

For additional details on computing Item 209-05, Sediment Removal, refer to Section 10.04.6.2.

10.08.2.10 ROCK SEDIMENT DAM (EC-STR-12)





ROCK SEDIMENT DAM

Rock Sediment Dam
(Photo currently not available)

10.08.2.10.1 DEFINITION AND PURPOSE

A rock sediment dam is a temporary structure composed of machined riprap with a facing of mineral aggregate (size 57) on the upstream side. This measure detains sediment laden stormwater runoff from a disturbed area in a pool in order to allow sediment to settle out. In addition, this structure provides a sediment filtration capacity as water passes through the smaller aggregate and a layer of geotextile fabric placed between the aggregate and the riprap.

10.08.2.10.2 APPROPRIATE APPLICATIONS

Rock sediment dams are considered temporary structures and may be used in waterways where the drainage area exceeds the limit for enhanced rock check dams. They should be applied in situations where sediment in runoff from a project cannot be fully controlled before entering the waterway. Examples of this may include bridge replacement projects with significant approach work, or situations where a relatively large stream runs either through, or immediately adjacent to the project site. This measure should be applied in channels with drainage areas of 50 acres or less.

Rock Sediment dams are for temporary use. Where a permanent facility is required consider the use of a sediment basin which can be converted into a permanent detention basin.

10.08.2.10.3 LIMITATIONS

The water impoundments created by a rock sediment dam can potentially cover very large areas. This measure should be used only where sufficient room can be obtained within the right-of-way or within drainage easements.

Rock sediment dams should not be used in designated Exceptional Tennessee Waters or stream with sensitive or endangered aquatic life. In addition, the use of this measure in a waterway may require an individual Aquatic Resources Alteration Permit from the Tennessee Department of Environment and Conservation and possibly a Section 404 permit from the U.S. Army Corps of Engineers, and this should be considered during the planning stages of the EPSC plan.

10.08.2.10.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is required in that the hydrologic and hydraulic analysis of the rock sediment dam is necessary to ensure its stability during the 25-year peak flow. For each rock sediment dam the height of the dam (D), height of the weir (D_o), width at the top of the dam (W), and length of the weir (B_W) should be provided in the EPSC plans.

Rock sediment dams should be constructed as shown on Standard Drawing EC-STR-12. The structure should be provided with an overflow weir 2 feet lower then the outer edges of the structure so that high flows will not create erosion at the point where the edges of the dam meet the natural ground. The width of this overflow weir is generally to be two thirds of the channel bottom width subject to a minimum bottom width of 4 feet. This will direct the main force of any overflows toward the center of the channel so that the potential for erosion on the sides of the channel will be reduced.

Rock sediment dams should be placed on geotextile fabric (Type IV) as described in the standard drawing. This fabric is necessary to prevent the piping of channel bed materials through the rock structure as well as to discourage any sliding of the riprap which may occur when there is significant ponding on the upstream side of the structure. A layer of geotextile fabric (Type III) should be placed between the upstream slope of the riprap and the mineral aggregate (size 57). This will increase the capacity of the structure to act as a filter.

Geotextile fabric (Type III) shall meet the requirements for the standard specifications for geotextiles, AASHTO designation M-288, Erosion Control. Geotextile fabric (Type IV) shall meet the requirements of the standard specifications for geotextile AASSHTO designation M-288, stabilization.

A rock sediment dam can potentially impound water to a depth of 8 or more feet during periods of high flow. This depth is sufficient that the designer should check for potential safety concerns related to the operation of the dam. For example, the flood pool during periods of high flow should be checked to ensure that no upstream structures or other property will be impacted.

As stated above, the bottom width of the overflow weir should ideally be two-thirds of the channel bottom width, subject to a minimum bottom width of 4 feet. The weir bottom width should be adequate to pass the peak discharge generated by the storm event specified in Section 10.05.1 without overtopping the structure. The table “Rock Sediment Dam Dimensions” on the standard drawing provides minimum weir bottom widths for increasing drainage areas. These weir widths should be adequate to pass the 5-year peak flow at a depth of 2.0 feet or less. In addition, the depth and velocity of flow over the structure should be checked for the 25-year event to ensure that the riprap would be stable under high-flow conditions.

Rock sediment dams shall be paid for under the following item numbers:

- 203-01, Road And Drainage Excavation (Unclassified), per CY
- 209-05, Sediment Removal, per CY
- 303-10.01, Mineral Aggregate (Size 57), per Ton
- 709-05.08, Machined Rip-Rap (Class B), per Ton
- 740-10.03, Geotextile (Type III) (Erosion Control), per SY
- 740-10.04, Geotextile (Type IV) (Stabilization), per SY

10.08.2.10.5 EXAMPLE APPLICATION

Given: A stream with a drainage area of 45 acres passes through a proposed roadway project in Williamson County. It has been decided that a rock sediment dam will be needed to supplement the other EPSC measures on the site in order to minimize the releases of sediment into the waterway. The stream cross section consists of a channel with a bottom width, BW, of 5.0 feet with 1.5H:1V side slopes (z_d = 1.5) up to a height, h_c, of 2.2 feet above the channel bottom. On the left side of the channel, the overbank slopes at 6H:1V (z_L = 6) to a height of about 9 feet above the channel bottom before opening out to relatively level ground. On the right side of the channel, the overbank slopes at 10H:1V (z_R = 10) to a similar height.

Find: Determine appropriate dimensions for the rock sediment dam and compute the required quantities.

Solution:

Step 1: Determine the dimensions of the rock sediment dam: Because the waterway is about 9 feet deep, it is decided to set the height of the dam (D on Standard Drawing EC-STR-12) at 8.0 feet. This is greater than the required minimum height of 4.3 feet specified by the table “Minimum Rock Sediment Dam Dimensions” on the standard drawing. Based on the table “Weir Height and Top Width” on the standard drawing, the height of the overflow weir, D_o, will be 6 feet and the top width of the dam, W, will be 6 feet. Two-thirds of the channel bottom width would be 3.3 feet; however, the length of the overflow weir will be the minimum value of 4.0 feet. The overflow weir will be 2 feet below the top of the structure. Based on the standard 3H:1V side slopes, the width at the top of the overflow will be 16 feet. In addition, it is determined that the overall length of the structure between the left and right overbanks will be 104.4 feet.

Step 2: Check flood flows over dam to ensure stability: If it is designed as specified on the standard drawing, the overflow weir should be adequate to pass the 5-year 24-hour peak flow rate without overtopping the dam. Thus, no further check is needed for that event. At this site, it is judged that the structure should be checked for the 25-year event in ensure that it will be adequate to pass the peak discharge without exceeding the top of the waterway; that is, without exceeding a depth of 9.0 feet.

Because the drainage area is less than 100 acres, the Rational Method is used to determine the flow rates to be used to check flows over the structure. Detailed discussions of how to determine parameters for the Rational Method are provided in Chapter 4 of this Manual. For this analysis, the time of concentration was determined to be 47 minutes. Since more than half of the watershed of the stream consists of undisturbed land upstream of the project, the runoff coefficient is determined to be 0.65. Since the project is located in Williamson County, the Shelbyville IDF curves presented in Figure 4A-11 are used to determine a 5-year rainfall intensity of 2.58 in/hr and a 25-year rainfall intensity of 3.56 in/hr. Thus:

$$Q_5 = (0.65)(2.58)(45) = 75.5 \text{ cfs}$$

and,

$$Q_{25} = (0.65)(3.56)(45) = 104.0 \text{ cfs}$$

As discussed above, the overflow weir will be adequate to pass the 5-year peak flow rate. However, the adequacy of the structure should still be checked for the 25-year event.

In order to assess the flow conditions which would occur at the peak of the 25-year event, flows on the overflow weir will be considered separately from flows on the remainder of the structure. Since a majority of the flow is likely to be conveyed by the overflow weir, it would experience much higher flow velocities than the other portions of the structure. As stated above, the bottom width of the weir will be 4.0 feet while the width at the top of the overflow will be 16 feet. Assuming that the flow depth will exceed the 2-foot height of the overflow, the effective weir length will be the average of these widths, or 10 feet. The weir length available on the remainder of the structure will be based on the total length across the top minus the 16-foot top width of the overflow, or 108 feet. The flow over both weir segments can be analyzed using the broad-crested weir equation as:

$$Q = CLH^{1.5}$$

Where: Q = flow rate, (ft^3)
C = the weir coefficient, equal to 3.0 in this case
L = effective weir length, (ft)
H = depth of flow over the weir, (ft)

It should be noted that the depth of flow on the overflow weir, H_o, will be 2 feet greater than the depth of flow over the remainder of the structure, H_w. Since the flow split between the overflow and the remainder of the structure is unknown, trial values of H_w are assumed until the sum of the flow rates computed for both segments of the structure equals the peak 25-year flow rate. The results of this trial-and-error analysis are presented in Table 10SC-4:

Weir Segment	Flow Depth (H) (feet)	Weir Length (feet)	Flow Rate (cfs)	Flow Area (ft^2)	Flow Velocity (ft/sec)
Main Structure	0.11	108.0	11.8	11.88	0.99
Overflow Weir	2.11	10.0	92.0	21.76	4.23

Table 10SC-4
Summary of Weir Flow Computations, Peak 25-Year Flow

The results shown on Table 10SC-4 bear out the initial assumptions made regarding the flow conditions on the structure; however, the flow velocities shown do not represent the highest flow velocities which would occur for these conditions. The flow will pass through critical depth as it moves over the downstream crest of the structure. Since the critical depths for each segment will be less than the weir flow depths, they represent the highest velocities. In computing the weir flow depths, it was assumed that there would be a level pool of water upstream of the structure so that the depth on the overflow weir would have to be 2 feet greater than the depth on the remainder of the structure. However, this restriction does not apply to computing critical depth on the downstream side of the structure and critical depth should be computed separately for each segment.

Critical depth may be determined by computing the Froude Number of the flow, Fr, as:

$$Fr = \frac{V}{\sqrt{gD}}$$

Where: Fr = Froude Number, which has a value of 1.0 for critical depth
V = velocity of the flow, (ft/sec)
D = hydraulic depth, (ft)

For an irregular cross section, the hydraulic depth is computed by dividing the cross sectional area of the flow by the top width. For the overflow weir, the top width will vary for depths up to 2 feet. For deeper depths, the top width would be 16 feet. Since the flow on the remainder of the structure essentially has a rectangular cross section, the hydraulic depth was considered to be equal to the actual depth. The flow velocity computed from Continuity Equation as $V = Q/A$, where Q is the flow rate as shown on Table 10SC-4 and A is the cross sectional area of the flow for critical depth. For each segment of the structure, trial depths were examined until a Froude Number value of 1.0 was computed. Table 10SC-5 presents a summary of these computations.

Weir Segment	Critical Depth (feet)	Flow Area (ft^2)	Top Width (feet)	Hydraulic Depth (feet)	Flow Velocity (ft/sec)	Froude Number
Main Structure	0.072	7.78	108.0	0.07	1.52	0.998
Overflow Weir	1.703	15.51	14.22	1.09	5.93	1.000

Table 10SC-5
Summary of Critical Depth Computations, Peak 25-Year, 24-Hour Flow

Since Class B Machined Riprap may be used for flow velocities up to 10 fps, the structure will remain stable for the 25-year storm event.

Step 3: Determine the required quantities: The pay items for this rock sediment dam will be:

<u>Item Number 709-05.08, Machined Rip-Rap (Class B), per Ton</u>

To compute the required quantity for this item, it is first necessary to compute the volume of machined riprap which will be required for the dam. However, the shape of the riprap structure will be somewhat complex; thus, it was divided into cross sectional slices from the left end of the structure to the right end. The cross sectional area was then computed for each cross sectional slice, and the volumes of rock between each of the slices was totaled. For example, at a distance 6 feet away from the left end of the structure, the ground surface would be at a height of 7 feet above the channel bottom. Since the structure is 8 feet high overall, the height of the structure at this slice would be 1 foot. Since W, the top width of the structure in the direction of the stream flow, is equal to 6 feet and the structure has 3H:1V side slopes, the base of the structure at the ground would be 12 feet. The cross sectional area of this slice is the average of the top and bottom widths times the height, or 9.0 ft^2. Similarly, the height of the ground 8 feet from the left end of the structure is 6.7 feet. Thus, the height of the structure is 1.3 feet and the width at the ground is 14 feet. This will result in a cross sectional area of 13.3 ft^2. The volume of rock between these two slices is thus:

$$Volume = \left[\frac{9.0+13.3}{2}\right](8-6) = 22.3 \text{ CF}$$

The volume between each successive slice is then totaled across the entire structure, accounting for the reduced structure height in the area of the overflow weir. Although for the sake of brevity these computations are not presented for this example, the total volume of rock is found to be 6950 CF. Dividing this by 27 CF/CY yields a volume of 257.4 CY, and further multiplying by 1.75 tons/CY yields the final quantity of 450.5 tons.

Item Number 303-10.01, Mineral Aggregate (Size 57), per Ton:

The required volume of mineral aggregate (size 57) may be computed as the surface area of the stone on the face of the riprap times the thickness of the stone layer. The surface area on the face of the riprap, in turn, may be computed by determining the vertical cross sectional area of the stone, and then adjusting for the slope of the face of the structure.

As shown in Section “B-B” on Standard Drawing EC-STR-12, the mineral aggregate will extend from the channel bottom to the level of the overflow weir, for a total height above the channel bottom of 6 feet. Given this height, it can be shown that the stone will begin and end at distances of 12.0 feet and 84.4 feet, respectively, from the left end of the structure. The area of the vertical projection of the mineral aggregate can then be computed by considering the height of the stone above significant break points in the stream cross section, as shown in Table 10SC-6:

Distance from Left End of Structure (feet)	Height of Ground (feet)	Height of Stone (feet)	Cumulative Area (ft^2)
12.0	6.0	0.0	0.0
34.8	2.2	3.8	43.3
38.1	0.0	6.0	59.5
43.1	0.0	6.0	89.5
46.4	2.2	3.8	105.7
84.4	6.0	0.0	177.9

Table 10SC-6
Summary of Cross Sectional Areas, Mineral Aggregate (Size 57)

The total vertical area of the mineral aggregate (size 57) is therefore 177.9 ft^2. Since the slope of the face of the structure is 3H:1V, the conversion factor from the vertical cross sectional area to the surface area along the slope may be computed as:

$$Conversion = \sqrt{3^2 + 1^2} = 3.16$$

The area along the slope is thus:

$$Area = 3.16(177.9) = 562.4 \text{ ft}^2$$

Since the aggregate layer is 1 foot thick, the required volume will be 562.4 CF. This may be converted to the final quantity in tons as:

$$562.4\,CF \times \frac{1\,CY}{27\,CF} \times \frac{1.49\,Tons}{CY} = 31.0 \text{ Tons}$$

Item Number 740-10.03, Geotextile (Type IV) (Stabilization), per SY:

The quantity of geotextile required for this item will be equal to the footprint area of the dam plus the area of the 3-foot wide fringe on the downstream side of the structure. Since the footprint area of the dam is somewhat complex, it was divided into slices in the same manner as above. Thus, for the slice 6 feet from the left end of the structure, the width of the material would be 12 feet plus 3 feet on the downstream side for a total of 15 feet. The width of the fabric 8 feet from the left end of the structure would be 14 feet plus 3 feet, or 17 feet. Thus, the area of the fabric between these two slices would be 32 ft^2. The areas between successive slices are totaled across the entire length of the structure to yield a final area of 3068 ft^2 which is equal to 340.8 SY.

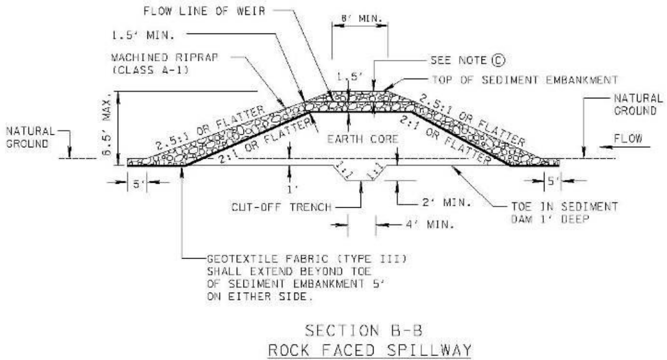
Item Number 740-10.03, Geotextile (Type III) (Erosion Control), per SY:

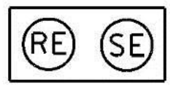
This item consists of a layer of fabric placed between the mineral aggregate (size 57) and the face of the riprap. The area of the mineral aggregate (size 57) along the face of the riprap was determined above to be 562.4 ft^2. Thus, the final quantity of fabric required would be 1124.9 SF or 125.0 SY.

Item Number 209-05, Sediment Removal, per CY

For additional details on computing Item 209-05, Sediment Removal, refer to Section 10.04.6.2.

10.08.2.11 ROCK AND EARTH SEDIMENT EMBANKMENT (EC-STR-13)





ROCK AND EARTH
SEDIMENT EMBANKMENT

Rock and Earth Sediment Embankment
(Photo currently unavailable)

10.08.2.11.1 DEFINITION AND PURPOSE

This measure consists of a temporary compacted earth embankment with no drainage outlet except for an overflow weir at the top of the structure. The portion of the embankment which contains the overflow weir is protected by a layer of machined riprap Class A-1 in order to provide protection against wash-outs during periods of high flow. Because the embankment essentially forms a temporary retention basin, it can achieve very high sediment removal rates; and thus, maybe useful at sites which drain to Exceptional Tennessee Waters or sediment-impaired streams.

10.08.2.11.2 APPROPRIATE APPLICATIONS

This measure can be used in ditches or to intercept flows from large graded areas. It should not be applied in streams, wetland, or other natural water resources.

Rock and earth sediment embankments are for temporary use. Where a permanent facility is required, consider the use of a sediment basin which can be converted into a permanent detention basin.

10.08.2.11.3 LIMITATIONS

The water impoundments created by a rock and earth sediment embankment can potentially cover very large areas. This measure should be used only where sufficient room can be obtained within the right-of-way or within drainage easements.

This measure does not provide any type of low-level outlet and may thus remain full between rainfall events. Thus, its efficiency as a sediment removal device will be affected by the length of time between successive rainfall events. In addition, it should not be considered to offer any amount of stormwater storage volume. Further, because it is not designed to accommodate very large rainfall events (e.g. – a 100-year event) it should not be considered as a permanent structure.

This measure is comparatively expensive to construct and maintain. It should be considered only where the duration of the construction project is sufficient to justify its use, or where other special site conditions require it.

10.08.2.11.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is required in that the hydrologic and hydraulic analysis of the rock and earth sediment embankment is necessary to determine the impoundment volume, and the dimensions of the rock and earth sediment embankment. For each rock and earth sediment embankment the height of the embankment, height of the weir, width at the top of the embankment, and length of the weir should be provided in the EPSC plans.

Rock and earth sediment embankments should generally be designed to impound the full runoff volume generated by the storm event specified in Section 10.05.1. At most sites, this volume will be that which is necessary to capture the 2-year/24-hour rainfall event. At sites that drain to Exceptional Tennessee Waters or sediment-impaired streams, the impoundment volume should be equal to the 5-year/24-hour event. Additionally, rock and earth sediment embankments should be dewatered using a Dewatering Structure (EC-STR-1) or Sediment Filter Bag (EC-STR-2) so that sufficient volume is available to accommodate runoff from the next storm event. The designer should consider this necessity and provide the appropriate items for dewatering in the project plans.

Although there is no maximum drainage area for the application of this measure, it should be utilized only at sites where the design impoundment volume can be limited to 15 acre-feet. As much as possible, off-site flows should be diverted around the storage area formed by the embankment.

The elevation of the overflow weir should be set such that any flows in excess of the design impoundment volume will be passed over the structure. The overflow weir must be designed to pass at least the full 25-year peak inflow rate with a minimum of 1 foot of freeboard to the top of the embankment. In determining the weir length, preference should be given to providing a longer weir length in order to minimize the flow depth on the weir. However, the height of the overflow should be at least 1.5 feet.

The existing soil beneath the "footprint" of the embankment should be excavated a depth of at least 1 foot prior to placing the compacted fill for the embankment. The embankment must also be provided with a cut-off trench along the centerline of the structure. This trench must extend at least one foot into a stable, impervious layer of soil and have a minimum depth of 2 feet in addition to the 1-foot excavation depth. The minimum bottom width should be at least wide enough to permit operation of compaction equipment but no less than 4 feet. The side slopes of the trench should be no steeper than 1H:1V. The excavated soil should be stockpiled outside of the impoundment area so that the area can be restored following removal of the structure.

In the area of the overflow, geotextile fabric (Type III) should be placed between the machined riprap and the earth core. This geotextile fabric should be extended 5 feet past the toe of the riprap slopes on both sides of the embankment in order to accommodate the required 5-foot long riprap keys. The geotextile fabric (Type III) shall meet the requirements of the standard specification for geotextiles, AASHTO designation M-288, Erosion Control.

Because this measure is typically not used for short-duration projects, the exposed slopes of the earth embankment should be provided with temporary seeding with mulch.

Rock and earth sediment embankments shall be paid for under the following item numbers:

- 203-01, Road and Drainage Excavation (Unclassified), per CY
- 209-05, Sediment Removal, per CY
- 709-05.06, Machined Rip-Rap (Class A-1), per Ton
- 740-10.03, Geotextile (Type III) (Erosion Control), per SY
- 801-01.07, Temporary Seeding (with Mulch) per Unit

10.08.2.11.5 EXAMPLE APPLICATION

Given: A portion of a roadway re-construction project is located in Grundy County. The project will be located in an area that drains to a stream designated as Exceptional Tennessee Waters. Because of the environmentally sensitive nature of the receiving stream, it will be a priority to maximize the quantity of sediment removed from the construction site runoff.

The length of roadway within the drainage area will be 2000 feet and the average width of the construction limits in this area will be 110 feet. This results in an onsite disturbed area of 5.051 acres. An offsite area of 9.861 acres drains towards the roadway, and this area consists primarily of rolling grass and pasture lands. A single cross drain conveys flows from the offsite area into a swale which extends 1300 feet to the receiving stream. This swale is grass covered and does not have a defined bed. Because of this, and because there appears to be adequate distance between the project and the receiving stream, it has been decided that a rock and earth sediment embankment will be suitable choice for this site.

Find: Determine appropriate dimensions for the rock and earth sediment embankment and compute the required quantities.

Solution:

Step 1: Determine the runoff volume to be retained by the embankment: Based on Section 10.05.1, the embankment should be designed to retain the runoff generated by the 5-year, 24-hour rainfall event. In order to determine this volume, the Curve Number Method, as described in the Chapter 4 of the NRCS *National Engineering Handbook (1972)* will be utilized. The county soil survey indicates that about 85% of the soils in the offsite drainage are in Hydrologic Soil Group C and the remaining 15% are in group B. Table 4A-3 specifies curve numbers of 74 and 61 for these soil groups for lands consisting of grassland or pasture in good condition. Thus, the composite curve number for the offsite area is 72.1. The soils within the project limits are all in group C. It is assumed that these soils area will be compacted and highly disturbed and a curve number of 91 is selected from Table 4A-1.

The Curve Number Method determines the volume of runoff from an area by first computing a factor S, which is related to the curve number as follows:

$$S = \frac{1000}{CN} - 10$$

For the offsite area, this parameter is computed as:

$$S = \frac{1000}{72.1} - 10 = 3.870$$

Once S has been determined, it is used in a second equation to compute the runoff volume, R, expressed as inches of depth on the watershed:

$$R = \frac{(P - 0.2S)^2}{P + 0.8S}$$

Where: R = runoff depth, (inches)
P = rainfall depth, (inches)
S = parameter determined above

As shown in Table 4A-6, the 5-year, 24-hour rainfall depth for Grundy County is 4.70 inches. Thus, for the offsite area, the 5-year, 24-hour runoff volume is computed as:

$$R = \frac{(P - 0.2S)^2}{P + 0.8S} = \frac{(4.70 - [0.2 \times 3.870])^2}{4.70 + [0.8 \times 3.870]} = 1.977 \text{ inches}$$

In order to convert this volume to acre-feet of runoff, it is necessary to multiply by the drainage area as:

$$V_{R/O} = 9.861\,ac \times 1.977\,in \times \frac{1\,ft}{12\,in} = 1.625 \text{ ac-ft}$$

In the same manner, an S value of 0.989 is computed for the onsite drainage area, which results in a runoff volume of 3.691 inches. Multiplying by the drainage area of 5.051 acres then yields a runoff volume of 1.554 ac-ft. Thus, the total 5-year, 24-hour runoff volume to be detained by the embankment is 3.179 ac-ft.

Step 2: Determine the required height of the embankment: Based on the site topography, it appears that the swale consists of a V-ditch with 10H:1V side slopes, at a slope of 0.8%. Based on this, it is possible to compute the surface area and volume of the pool created by the embankment for increasing depth, as shown in Table 10SC-7. For the sake of simplicity, the storage volume available on the sloping face of the embankment is not considered in these computations.

Based on these results, it is decided to place the overflow weir at a height of 7.0 feet above the flow line of the swale, as this is the lowest height (to the nearest 0.5 feet) which provides a storage volume greater than the 5-year, 24-hour runoff volume of 3.179 ac-ft. It is further decided to limit the height of the embankment over the overflow weir, to 1.5 feet which results in an embankment height of 8.5 feet. It should be noted that the height of the earth core in the overflow section of the structure will be 5.5 feet, and that the volume impounded at that depth is only slightly more than half of the volume impounded at the height of the overflow. Thus, nearly half of the stored water would be able to trickle through the structure between rainfall events which would tend to improve the performance of the structure in the event that two rainfall events occur over a relatively short period of time.

As stated in the Design Criteria, a freeboard of 1.0 feet is required between the depth of flow on the overflow in the 25-year event and the top of the embankment. Since the weir height was determined to be 1.5 feet, the maximum design impoundment depth will be 7.5 feet, at which the length of the pool will be about 940 feet. In order to prevent the impounded pool from backing up into the project area, it is decided to place the centerline of the structure 1020 feet downstream of the roadway centerline.

Depth (feet)	Length of Pool (feet)	Width of Pool (feet)	Surface Area (ac)	Storage Volume (ac-ft)
0.00	0.0	0.0	0.000	0.000
0.50	62.5	10.0	0.007	0.002
1.00	125.0	20.0	0.029	0.011
1.50	187.5	30.0	0.065	0.034
2.00	250.0	40.0	0.115	0.079
2.50	312.5	50.0	0.179	0.152
3.00	375.0	60.0	0.258	0.262
3.50	437.5	70.0	0.352	0.414
4.00	500.0	80.0	0.459	0.617
4.50	562.5	90.0	0.581	0.877
5.00	625.0	100.0	0.717	1.202
5.50	687.5	110.0	0.868	1.598
6.00	750.0	120.0	1.033	2.073
6.50	812.5	130.0	1.212	2.635
7.00	**875.0**	**140.0**	**1.406**	**3.289**
7.50	937.5	150.0	1.614	4.044
8.00	1000.0	160.0	1.837	4.907
8.50	1062.5	170.0	2.073	5.884
9.00	1125.0	180.0	2.324	6.984

Table 10SC-7
Summary of Storage Volume Computations

Step 3: Determine the peak flow rates into the embankment: In order to determine the length of the overflow weir, it is first necessary to determine the flow rates into the impoundment created by the embankment. Since the combined drainage area of the onsite and offsite areas is 14.912 acres, it will be possible to use the Rational Method to compute these flow rates, as described in Section 4.04. Runoff coefficients for the offsite and onsite areas were determined from Table 4-2 to be 0.5 and 0.8, respectively. However, in computing the composite runoff coefficient, it is necessary to account for the rainfall which will occur on the impounded water. Thus, the runoff coefficient is computed as shown in Table 10SC-8.

Subarea	Area (ac)	C	CA
Offsite	9.861	0.5	4.931
Onsite	5.051	0.8	4.040
Full Basin	1.046	1.0	1.406
TOTAL	**16.318**	**0.64**	**10.377**

Table 10SC-8
Composite Runoff Coefficient Computations

Although details of the time of concentration computations are not presented here, it was assumed that the flow time through the cross drain into the impoundment would be insignificant. Thus, this parameter was computed based only on the offsite area, and was found to be 22.6 minutes. Because the site is located in Grundy County, the Manchester IDF curves, as presented in Figure 4A-10 are used to determine a 5-year, 24-hour rainfall intensity of 3.92 in/hr and a 25-year, 24-hour rainfall intensity of 5.20 in/hr. These are multiplied by the total “CA” in Table 10SC-8 to compute peak flow rates of 40.7 cfs and 54.0 cfs, respectively.

Step 4: Determine the required overflow weir length: The length of the overflow weir will be computed using Equation 8-24 (see Section 8.05). As stated above, the maximum depth desired on the overflow in the 25-year, 24-hour storm is 0.5 feet. Thus, Equation 8-24 is re-written and solved as:

$$L = \frac{Q}{CH^{1.5}} = \frac{54.0}{(3.0)(0.5^{1.5})} = 50.9 \text{ feet}$$

It should be noted that the length computed here is the *effective* weir length, which for a trapezoidal weir will be longer than the actual bottom width of the overflow weir. However, since the depth is 0.5 feet, this factor will be ignored and the design overflow weir length will be rounded to 51 feet.

Step 5: Determine the required quantities: Even though the swale will have a relatively simple V-ditch cross section, the shape of the proposed embankment will be somewhat complicated. In order to simplify and organize these computations, the following approach was taken. First, the structure was divided into three sections: the two “end” sections composed entirely of soil, and the middle section which is composed of both rock and soil and contains the overflow weir. Given 3H:1V side slopes and a 51-foot bottom width, the overflow section would have a top width of 60 feet. Further, since the riprap is to extend a minimum width of 15 feet on either side of the overflow, the total width of the overflow section, will be 90 feet. Since the overall length of the structure is 170 feet, the two sections on either side of the overflow section would be 40 feet long. Each of the sections is then divided into 5-foot wide “slices”, with the “X” distance for each “slice” measured from the point at which the left edge of the structure intersects the natural 10H:1V slope of the swale. The determination of each quantity, then, will be based on working across the structure at 5-foot intervals, determining the transverse widths (i.e. – in the direction of the stream flow) of the top and bottom of the embankment, as well as its height. The actual computation of the quantities can then proceed from that basic data. It should be noted that the first section extends from an “X” distance of 0 to an "X" distance of 40 feet; the middle, overflow section extends from 40 feet to 130 feet, and the third section extends from 130 feet to 170 feet.

Item Number 203-01, Road and Drainage Excavation (Unclassified), per Cubic Yard

This item includes both the excavation required to prepare the embankment foundation and the construction of the compacted embankment itself, and it will thus be computed in two parts. As shown on the standard drawing, the excavation for the foundation is 1 foot deep and extends 5 feet past the points at which the two faces of the compacted embankment touch the natural ground. Thus, for each 5-foot increment, it is necessary to determine the structure height in order to determine the width of the structure at ground level. This width is then increased by 10 feet and multiplied by 1 foot in order to determine the cross sectional area of the excavation. This cross sectional area must also be increased by the area of the cutoff trench, which is 12 SF. This computation is summarized in Table 10SC-9a:

Distance from Left End of Structure (feet)	Height of Structure (feet) [1]	Width at Toe of Structure (feet)	Width of Excavation (feet)	Cross Sectional Area of Excavation (ft^2) [2]	Cumulative Volume of Excavation (ft^3)
0	0.00	8.0	18.0	30.0	0.0
5	0.50	10.5	20.5	32.5	156.3
10	1.00	13.0	23.0	35.0	325.0
15	1.50	15.5	25.5	37.5	506.3
20	2.00	18.0	28.0	40.0	700.0
25	2.50	20.5	30.5	42.5	906.3
30	3.00	23.0	33.0	45.0	1125.0
35	3.50	25.5	35.5	47.5	1356.3
40	4.00	28.0	38.0	50.0	1600.0

Table 10SC-9a
Computation Summary: Excavation for the Left End of the Embankment

Notes: [1] Distance from the top of the embankment to the toe at the existing ground line.
[2] Includes 12 ft^2 for the cut-off trench.

The excavated volume for the left section of the structure is found to be 1600.0 ft^3. Since the right section of the structure is essentially identical to the left, the total excavated volume for the two end sections is 3200.0 ft^3. The computations for the middle overflow section are done in the same manner and are summarized in Table 10SC-9b. The excavation for the middle overflow section is found to be 5512.5 ft^3 and the total is thus 8712.5 ft^3. This is divided by 27 to yield an excavation quantity of 322.7 CY.

The second part of the computations for this item is to compute the volume of the compacted earth embankment. It should be noted that the computations for the two ends of the structure will be different from the computations for the middle overflow section. For the two ends of the structure, the computations will consider only the volume above the natural ground line, while the computations for the middle overflow section will compute the volume down to the bottom of the excavated foundation. These computations will proceed by determining the top and bottom widths of the embankment for each 5-foot increment. This will allow the cross sectional area at each "slice" to be computed, which in turn allows a computation of volume. Table 10SC-9c summarizes these computations for the two ends of the structure. These computations show that, above the natural ground level, the volume of the embankment on each end will be 1177.5 ft^3. However, in order to determine the total volume of compacted embankment, it is necessary to add back in the excavation necessary to prepare the foundation, which was determined above to be 1600.0 ft^3 for the left section. Thus, the total compacted embankment volume for one end is found to be 2777.5 ft^3, and for both ends, 5555.0 ft^3.

Distance from left end of structure (feet)	Height of structure (feet) [1]	Width at toe of structure (feet)	Width of excavation (feet)	Cross sectional area of excavation (ft^2) [2]	Cumulative volume of excavation (ft^3)
40	4.00	28.0	38.0	50.0	0.0
45	4.50	30.5	40.5	52.5	256.3
50	5.00	33.0	43.0	55.0	525.0
55	5.50	35.5	45.5	57.5	806.3
59.5	5.95	37.8	47.8	59.8	1070.1
65	6.50	40.5	50.5	62.5	1406.3
70	7.00	43.0	53.0	65.0	1725.0
75	7.50	45.5	55.5	67.5	2056.3
80	8.00	48.0	58.0	70.0	2400.0
85	8.50	50.5	60.5	72.5	2756.3
90	8.00	48.0	58.0	70.0	3112.5
95	7.50	45.5	55.5	67.5	3456.3
100	7.00	43.0	53.0	65.0	3787.5
105	6.50	40.5	50.5	62.5	4106.3
110.5	5.95	37.8	47.8	59.8	4442.4
115	5.50	35.5	45.5	57.5	4706.3
120	5.00	33.0	43.0	55.0	4987.5
125	4.50	30.5	40.5	52.5	5256.3
130	4.00	28.0	38.0	50.0	5512.5

Table 10SC-9b
Computation Summary: Excavation for the Middle Section of the Embankment

Notes: [1] Distance from the top of the embankment to the toe at the existing ground line.
[2] Includes 12 ft^2 for the cross-sectional area of the cutoff trench.

Table 10SC-9d summarizes the compacted embankment volume computations for the middle overflow section. The earth core in this section is 3 feet lower than the height of the embankment on the two ends. Thus, these computations are based on a height of 5.5 feet above the flow line of the swale as well as 2H:1V side slopes, as shown on the standard drawing. It is important to emphasize that the computations for the middle section include the entire compacted earth embankment down to the bottom of the excavated depth, including the cutoff trench. Although this is somewhat confusing for the computing the quantity of compacted earth, it greatly simplifies the determination of the riprap quantity. Because the cross sectional area computed for the embankment at each increment already includes a portion of the excavated area, it is not necessary to add this area back in, as was done for the two end sections. Thus, the total volume of compacted earth in the middle section is computed to be 7702.6 ft^3. The total earth embankment volume for all three sections of the embankment is thus 13,257.6 ft^3 or 491.0 CY. Adding the excavation volume determined above results n a final quantity of 813.7 CY.

Distance from left end of structure (feet)	Height of structure (feet) [1]	Width at toe of structure (feet)	Cross sectional area of embankment (ft^2)	Cumulative volume of embankment (ft^3) [2]
0	0.00	8.0	0.0	0.0
5	0.50	10.5	4.6	11.6
10	1.00	13.0	10.5	49.4
15	1.50	15.5	17.6	119.7
20	2.00	18.0	26.0	228.8
25	2.50	20.5	35.6	382.8
30	3.00	23.0	46.5	588.1
35	3.50	25.5	58.6	850.9
40	4.00	28.0	72.0	1177.5

Table 10SC-9c
Computation Summary: Embankment Volume for the Left End of the Embankment

Notes: [1] Distance from the top of the embankment to the toe at the existing ground line.
[2] This parameter represents only the volume above the ground line.

<u>Item Number 709-05.06, Machined Rip-Rap (Class A-1), per Ton</u>

As indicated on the standard drawing, riprap is to be included only on the middle, overflow section of the rock and earth sediment embankment. The determination of the quantity of this material is complicated by its relatively complex shape. For example, while the sides of the earth core are to be given a 2H:1V slope, the side slopes of the overall structure are at a 2.5H:1V slope. In addition, a portion of the area excavated for the foundation will be occupied by the earth core while the remaining volume will be occupied by stone. In order to determine the required volume of riprap, the volume of the entire middle section of the structure, including both rock and earth is determined first, down to the bottom of the excavated foundation. Since the volume of the earth core was determined above, the volume of machined riprap will simply be the difference between the total volume of the middle section and the volume of the earth core.

The volume of the middle portion of the structure will be determined in the same manner as the preceding computations, in that the cross sectional area of the structure will be computed at 5-foot increments. However, in this computation, it will be necessary to account for the overflow weir by reducing the height of the structure and appropriately increasing its transverse top width. These computations are summarized in Table 10SC-9e, which shows that the total volume of the middle section is 18,212.5 ft^3. Since the volume of the earth core was determined above to be 7702.6 ft^3, the net volume of machined riprap is 10,510.1 ft^3 or 389.3 CY. As described in Section 10.04, the final quantity in tons may be computed by multiplying the volume in CY by 1.75. Thus the final quantity for machined riprap Class A-1 is 682.1 tons.

Distance from left end of structure (feet)	Height of structure at bottom (feet) [1]	Width at bottom of excavation (feet)	Cross sectional area of embankment (ft^2) [2]	Cumulative volume of embankment (ft^3)
40	2.00	16.0	36.0	0.0
45	2.50	18.0	44.5	201.3
50	3.00	20.0	54.0	447.5
55	3.50	22.0	64.5	743.8
59.5	3.95	23.8	74.8	1057.2
65	4.50	26.0	88.5	1506.3
70	5.00	28.0	102.0	1982.5
75	5.50	30.0	116.5	2528.8
80	6.00	32.0	132.0	3150.0
85	6.50	34.0	148.5	3851.3
90	6.00	32.0	132.0	4552.5
95	5.50	30.0	116.5	5173.8
100	5.00	28.0	102.0	5720.0
105	4.50	26.0	88.5	6196.3
110.5	3.95	23.8	74.8	6645.4
115	3.50	22.0	64.5	6958.8
120	3.00	20.0	54.0	7255.1
125	2.50	18.0	44.5	7501.3
130	2.00	16.0	36.0	7702.6

Table 10SC-9d
Computation Summary: Earth Core Volume for the Middle Section of the Embankment

Notes: [1] Distance from the top of the earth core to the bottom of the excavated foundation.
[2] This parameter includes 12 ft^2 for the cross sectional area of the cutoff trench.

Item Number 740-10.03, Geotextile (Type III) (Erosion Control), per SY

Coverage by geotextile fabric will be required on all areas where the machined riprap interfaces with earthen materials, including both the earth core and the excavated areas. Thus, the first part of this computation will involve computing, at each 5-foot increment along the middle section of the structure, the length of a line which includes:

a.) the 1-foot length from the natural ground to the bottom of the excavated area,
b.) the distance from the outer edge of the excavation to the bottom of the earth core,
c.) the distance along the inclined face of the earth core,
d.) the distance along the top of the earth core, and
e.) the corresponding lengths along the face of the core and excavated area on the other side of the structure.

Distance from Left End of Structure (feet)	Width at Top of Structure (feet)	Height of Structure (feet)	Width at Toe of Structure (feet)	Cross Section Area Above Toe (ft^2)	Cross Section Area Below Toe (ft^2)	Total Cross Section Area (ft^2)	Cumulative volume of Structure (ft^3)
40	8.0	4.0	28.0	72.0	50.0	122.0	0.0
45	8.0	4.5	30.5	86.6	52.5	139.1	652.8
50	8.0	5.0	33.0	102.5	55.0	157.5	1394.4
55	8.0	5.5	35.5	119.6	57.5	177.1	2230.9
59.5	15.5	4.5	37.8	118.5	59.8	178.2	3030.5
65	15.5	5.0	40.5	140.0	62.5	202.5	4077.5
70	15.5	5.5	43.0	160.9	65.0	225.9	5148.4
75	15.5	6.0	45.5	183.0	67.5	250.5	6339.4
80	15.5	6.5	48.0	206.4	70.0	276.4	7656.6
85	15.5	7.0	50.5	231.0	72.5	303.5	9106.3
90	15.5	6.5	48.0	206.4	70.0	276.4	10,555.9
95	15.5	6.0	45.5	183.0	67.5	250.5	11,873.1
100	15.5	5.5	43.0	160.9	65.0	225.9	13,064.1
105	15.5	5.0	40.5	140.0	62.5	202.5	14,135.0
110.5	15.5	4.5	37.8	118.5	59.8	178.2	15,182.0
115	8.0	5.5	35.5	119.6	57.5	177.1	15,981.6
120	8.0	5.0	33.0	102.5	55.0	157.5	16,818.1
125	8.0	4.5	30.5	86.6	52.5	139.1	17,559.7
130	8.0	4.0	28.0	72.0	50.0	122.0	18,212.5

Table 10SC-9e
Computation Summary: Structure Volume for the Middle Section of the Embankment
(Includes both rock and earth)

For each increment, the average of the computed lengths is multiplied by the distance between each "slice" to compute the surface area of fabric needed, as shown in Table 10SC-9f. The total area computed in this manner is 4793.1 ft^2.

The second part of this computation involves determining the area of fabric which would be required along the sides of the overflow section, where the riprap interfaces with the two end sections of the sediment embankment. As noted above, the total cross sectional area of the embankment above the toe at a point 40 feet from the left end of the structure will be 72.0 ft^2 and the cross sectional area of the excavated portion below the toe will be 50.0 ft^2, for a total of 122.0 ft^2. It has also been determined that the cross sectional area of the earth core down to the bottom of the excavated area at this location will be 36.0 ft^2. The net cross sectional area is thus 86.0 ft^2. Doubling this to account for both sides results in an area of 172.0 ft^2. Combining this with the result of the first computation results in a total area of 4965.1 ft^2 for geotextile fabric. This area is then divided by 9 ft^2/SY to yield the final quantity of 551.7 SY.

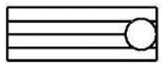
Distance from Left End of Structure (feet)	Width of Excavation (feet)	Width at Base of Earth Core (feet)	Height of Earth Core (feet)	Total of Lengths a - e (feet)	Cumulative Surface area (ft^2)
40	38.0	16.0	2.00	40.94	0.0
45	40.5	18.0	2.50	43.68	211.6
50	43.0	20.0	3.00	46.42	436.8
55	45.5	22.0	3.50	49.15	675.7
59.5	47.8	23.8	3.95	51.61	902.5
65	50.5	26.0	4.50	54.62	1194.6
70	53.0	28.0	5.00	57.36	1474.6
75	55.5	30.0	5.50	60.10	1768.2
80	58.0	32.0	6.00	62.83	2075.5
85	60.5	34.0	6.50	65.57	2396.5
90	58.0	32.0	6.00	62.83	2717.6
95	55.5	30.0	5.50	60.10	3024.9
100	53.0	28.0	5.00	57.36	3318.5
105	50.5	26.0	4.50	54.62	3598.5
110.5	47.8	23.8	3.95	51.61	3890.6
115	45.5	22.0	3.50	49.15	4117.4
120	43.0	20.0	3.00	46.42	4356.3
125	40.5	18.0	2.50	43.68	4581.5
130	38.0	16.0	2.00	40.94	4793.1

Table 10SC-9f
Computation Summary: Surface Area of Erosion Control Fabric (Type III) (Erosion Control) for the Middle Section of the Embankment

Item Number 209-05, Sediment Removal, per CY

For additional details on computing Item 209-05, Sediment Removal, refer to Section 10.04.6.2.

10.08.2.12 SEDIMENT BASIN (EC-STR-15, 16, 17 AND 18)



SEDIMENT BASIN

Sediment Basin
Location: SR-37, Carter County, TN (2004)

10.08.2.12.1 DEFINITION AND PURPOSE

A sediment basin is an excavated reservoir which usually includes an embankment, an impoundment area, an outlet riser with a principal spillway outlet pipe through the embankment, a surface dewatering (drawdown) device, and an emergency spillway. The outlet of this type of basin is designed to detain stormwater runoff from a disturbed area for an extended time, allowing the sediment to settle out while cleaner water is discharged from the surface of the basin. This reduces the quantity of sediment in the water released from the sediment basin, thus protecting the receiving waters from potential damage.

10.08.2.12.2 APPROPRIATE APPLICATIONS

Sediment basins shall be used at project locations where a drainage area of 10 acres or more discharges to a single outfall location. When an outfall drains to Exceptional Tennessee Waters or a sediment-impaired stream, a sediment basin shall be used if the contributing drainage area to the outfall is 5 acres or more. The acreage limitations provided above include both disturbed and undisturbed areas draining to the outfall; however, diverted areas within the outfall's watershed may be omitted from the computed area.

A sediment basin may be used where there is sufficient space and suitable topography for its construction. At the completion of construction, the temporary basin should either be removed or reconstructed to serve a permanent purpose such as for stormwater detention.

Equivalent control measures may be used in lieu of sediment basins at project sites when suitable topography or sufficient space is unavailable.

10.08.2.12.3 LIMITATIONS

The maximum drainage area for a temporary sediment basin shall not exceed 50 acres.

Safety precautions shall be considered when designing and specifying a temporary sediment basin on a project site. Limits on embankment height and impoundment volume should be maintained to keep this temporary EPSC device from being classed as a dam per the Safe Dams Act (see Chapter 8).

Temporary sediment basins are generally not suitable for use on steep terrain where embankment heights can easily exceed 20 feet measured from the top of the embankment to the outlet end of the principal spillway pipe due to the grade of the receiving channel. The potential for sliding failure of the entire embankment, inability to achieve necessary volumes, and the difficulty in removing the basin and its components at the completion of the project generally limits its use on steep grades.

Sediment basins shall not be constructed in an existing stream; rather, they should be located to trap sediment before it enters a stream. Use of a sediment basin in a designated floodplain should be avoided where possible. Other sediment trapping devices and methods should be considered by the designer rather than placing significant amounts of fill in a floodplain, especially in urban areas where adverse flooding could result.

10.08.2.12.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is required. Various details are provided on Standard Drawings EC-STR-15 through 18. All design information shown in Table 10SC-10 should be provided in the EPSC plans. In addition, details showing the floating outlet structure dewatering system and baffle configuration (where needed) should be included in the EPSC plans for each sediment basin on the project. Details for the floating outlet structure should show the size of the orifice (FOS_D) used to dewater the sediment basin over a minimum 72 hour time period.

A sediment basin may remain in place after completion of the project to serve a permanent purpose, as indicated in the plans or as directed by the engineer. Usually, this will require the removal of accumulated sediments from the basin and the reconstruction of the outlet. Additional grading to enlarge the basin, re-shaping and stabilization of the slopes, modification or replacement of the riser, and adjustments to the emergency spillway and outlet channels may be required. Permanent facilities are usually designed to accommodate larger rainfall events than a temporary facility. Hydraulic calculations for temporary basins that are to be converted for permanent use should be reviewed by the Hydraulic Section of the Structures Division.

Any embankment 20 feet or more in height, or which can store 30 acre-feet or more of runoff may be considered a dam and would meet the requirements established by the Tennessee Safe Dams Act. It is unlikely that a sediment basin will meet either of these criteria if it is designed for temporary use according to the criteria presented in this section. However, if attempting to use a basin on steep terrain (mountain ravines, etc.) the embankment height could easily approach the 20 foot limit even with a relatively small water surface area in the basin; and thus, the designer should consider using other equivalent measures in lieu of the basin. Where it appears that a proposed structure will meet either of these criteria and no other option is available, the design should be referred to the Hydraulics Section.

A sediment basin should be designed to store the entire runoff volume generated by the design storm specified in Section 10.05.1.3 for the contributing drainage area to the basin.

BASIN DIMENSIONS		
LENGTH OF BASIN FLOOR	L	
WIDTH OF BASIN FLOOR	W	
SIDE SLOPE OF BASIN (INTERIOR)	H:1V	
SIDE SLOPE OF BASIN (EXTERIOR)	H:1V	
DESIGN ELEVATIONS		
BASIN FLOOR ELEVATION AT RISER		
SEDIMENT CLEANOUT ELEVATION		
WET SEDIMENT STORAGE ELEVATION		
DRY SEDIMENT STORAGE ELEVATION		
DESIGN STORMWATER STORAGE ELEVATION		
RISER CREST ELEVATION		
EMERGENCY SPILLWAY ELEVATION		
25-YEAR STORM HIGHWATER ELEVATION		
TOP OF EMBANKMENT ELEVATION		
PRIMARY OUTLET DIMENSIONS		
FLOATING OUTLET STRUCTURE ORIFICE DIAMETER	FOS_D	
RISER PIPE DIAMETER[1]	D_R	
OUTLET PIPE DIAMETER	D_P	
OUTLET PIPE LENGTH	L_{PIPE}	
OUTLET PIPE INLET INVERT ELEVATION		
OUTLET PIPE OUTLET INVERT ELEVATION		
OUTLET PIPE SLOPE	S_P	
LENGTH OF RIPRAP APRON	L_O	
BOTTOM WIDTH OF OUTLET DITCH	X_0	
DEPTH OF OUTLET DITCH	D_0	
OUTLET DITCH LINING		
EMERGENCY SPILLWAY DIMENSIONS		
WIDTH OF EMERGENCY SPILLWAY	B	
DEPTH OF EMERGENCY SPILLWAY	D_3	
LENGTH OF RIPRAP APRON	L_O	
BOTTOM WIDTH OF OUTLET DITCH	X_1	
DEPTH OF OUTLET DITCH	D_1	
OUTLET DITCH LINING		
OUTLET DITCH DIMENSIONS		
BOTTOM WIDTH OF OUTLET DITCH	X_2	
DEPTH OF OUTLET DITCH	D_2	
OUTLET DITCH LINING		

[1] Where acceptable, the Square Concrete No. 42 Catch Basin may be used in lieu of using a round standpipe for the riser. See D-CB-42 for details.

Table 10SC-10
Sediment Basin Dimensions

Where possible, runoff from undisturbed project areas and off-site “run-on” flows should be diverted away from and around all proposed sediment basins. The designer is not required to correct existing upslope problems or capture run-on eroded sediments from adjacent areas that drain onto the project. When this is occurring (or the potential exists) diversions become critical in controlling both the final size of the sediment basin and the sediment load expected into the basin. TDOT basins should be designed to capture only the runoff from disturbed areas *on the TDOT project*. When runoff cannot be diverted, the minimum basin volume must be computed using the entire watershed that will drain into the basin. The volume and area required for using this EPSC device may be reduced by using diversions. Watershed areas that will NOT be disturbed are NOT required to be treated. Thus, these undisturbed areas should be diverted away from sediment basins where at all possible. Mixing runoff from undisturbed areas with runoff from disturbed areas will ultimately reduce the overall water quality discharging from the entire watershed.

Sediment basins shall not have an outlet that provides an opening at the bottom of the basin. Rather, all temporary sediment basins shall utilize outlet structures that draw water from the surface or near the surface of the basin; whereby, the cleanest water in the basin is discharged first, allowing sediments to settle out from the lower levels of the basin. Discharge from a sediment basin by other means (i.e. pumping) will not be allowed unless treatment of the pumped water is provided at the discharge point.

The principal spillway of the basin usually includes the following four components:

- **Floating Outlet Structure:** All sediment basins constructed as part of a TDOT project shall utilize a floating outlet structure (drawdown device) that discharges water in the basin from at or near the water surface. The floating outlet structure shall be designed to discharge the dry sediment storage area (volume) in no less than 72 hours. The floating outlet structure shown on EC-STR-18 shall be the primary means for draining the retained water in the dewatering zone (dry sediment storage volume) down to the wet sediment storage elevation. A procedure for selecting the orifice diameter (FOS_D) is provided on the Standard. See additional discussion below regarding sediment storage areas, volumes, and floating outlet structures.

- **Outlet Riser:** This portion of the principal spillway consists of a vertical corrugated metal standpipe or concrete Number 42 Catch Basin connected to the inlet end of the outlet pipe (D_P) through the embankment. When corrugated metal pipe is used for the riser, the diameter of the riser (D_R) should be selected based on the riser inflow curves shown in Figure 10A-5 in the Appendix. This pipe has solid walls so that water can enter this pipe only at the top, which should be at an elevation corresponding to the design storm water storage elevation. When a concrete riser is used, it should be constructed using Standard Drawing D-CB-42S and shall include the grate unit shown on the Standard for safety and debris control. The only opening in the riser walls should be that which is necessary for connecting the floating outlet structure and the opening for the outlet pipe. The center of the opening for the floating outlet structure should be at the computed wet sediment storage elevation.

- **Concentric Trash Rack and Anti-vortex Device:** When an outlet riser is constructed utilizing corrugated metal pipe, the riser should also include a vertical section (cylinder) of pipe placed over the top of the standpipe to form a hood. The cylinder is provided with a solid lid so that water flowing into the riser must pass through the gap between the riser and the cylinder. This prevents the formation of a vortex, which not only improves the hydraulic efficiency of the metal riser, but also prevents sediments from being stirred up, thus minimizing the quantity of sediment released from the basin. Design information for the trash rack and anti-vortex device is provided on Standard Drawing EC-STR-16. Where a concrete Number 42 catch basin is used for the riser, it shall include the Number 42 Grate for a trash rack.

- **Outlet pipe through the embankment:** For a sediment basin with an emergency spillway, this pipe should be sized to convey the design peak inflow rate with a headwater elevation which not will interfere with the operation of the principal outlet riser. Where the basin does not have an emergency spillway, this pipe should have sufficient capacity to pass the entire 25-year storm event. The designer will provide the invert elevations at both ends of the pipe and the slope of the pipe (S_P) on Table 10SC-10. The outlet pipe should also be provided with at least one anti-seep collar as well as a riprap apron at the outfall. Details for anti-seep collars can be found on EC-STR-16 and the design procedure is provided in Chapter 8 of this Manual. Design procedures for the riprap apron are provided in Section 6.05.5 of this Manual.

Usually, the designer should determine five different elevations within the storage volume of the basin. These elevations will correspond with, and be directly related to: 1.) the geometry of the proposed basin, 2.) the area draining to the basin, and finally, 3.) the design storm as determined by the receiving stream to which the basin will ultimately discharge into. As previously discussed, the basin design should attempt to capture only project related disturbed areas – all other areas should be diverted where possible. The five design elevations of a temporary sediment basin are:

- **"Wet" Sediment Storage Elevation:** Half of the sediment storage area provided in the basin should be below the lowest achievable elevation of the floating outlet structure. The top of the stone pad shown on EC-STR-18 should be set at this elevation. Since there will be no outlet for water stored below this elevation, this represents the permanent pool elevation of the basin. Thus, this volume is termed the "wet" sediment storage area because the retained sediment below this elevation should normally be saturated (underwater) except during drought conditions and where infiltration and evaporation will occur. The volume in the basin below this surface elevation should be equivalent to 67 cubic yards per acre (1809 ft^3 per acre) of contributing drainage area to the basin. Diverted areas may be omitted from this calculation. The permanent pool enhances settling between storm events and reduces the potential for re-suspension of sediment.

- **Sediment Cleanout Elevation:** The sediment cleanout elevation should correspond to half of the required "wet" sediment storage volume, or computed as 34 cubic yards per acre of contributing drainage area to the sediment basin. Diverted areas may be omitted from this calculation. Once sediment has accumulated to one-half of the original "wet" sediment storage volume of the basin (to the sediment cleanout elevation shown on the Standard Drawings), the basin should be cleaned. It should be noted that this elevation represents half of the available "wet" sediment storage *volume* and not half of the wet depth. The sediment cleanout elevation should be delineated with an elevation marker in the basin such as on the riser or a 4" x 4" post. The designer should also note that the sediment cleanout elevation will normally be under water, and thus an acceptable marker should be one that provides a known reference elevation above the permanent pool elevation from which to measure down to the top of the accumulated sediment.

- **“Dry” Sediment Storage Elevation:** The dry sediment storage elevation should be set at an elevation which corresponds to an additional 67 cubic yards per acre (1809 ft^3) of contributing area, or simply it is the water surface elevation in the basin that corresponds to a volume of 134 cubic yards per acre of contributing drainage area. Since water in this portion of the total sediment storage volume will be drawn down by the floating outlet structure, it is termed the “dry” sediment storage area. The depth in the basin at this elevation should normally be at least 4 feet. The elevation difference between the “wet” and “dry” sediment storage elevations should not be less than 1 foot. The “dry” sediment storage volume is to be completely dewatered over time, but no less than 72 hours.

- **Design Storm Water Storage Elevation:** As stated previously, the basin should be designed to contain the entire runoff volume from the storm event specified in Section 10.05.1.3 above the wet sediment storage elevation (assumed to be the starting point due to permanent pool). The design storm water storage volume should be no less than 134 cubic yards per acre of contributing drainage area into the basin. The top of the outlet riser should be set at the elevation corresponding to the design storm water storage volume, or preferably approximately 6 inches above the design storm water storage elevation so as to provide some additional volume for storm storage due to built-up sediment, grading irregularities, and lost volume due to installed devices such as baffles, risers, stone pad, etc.

- **25-Year Storm High Water Elevation:** Because a sediment basin is considered a temporary structure, the emergency spillway may be designed based on the 25-year storm event. Where an emergency spillway is used, the elevation difference between the top of the outlet riser and the emergency spillway crest should not be less than 1 foot. Further, the top of the embankment must be at least 1 foot above the computed 25-year high water elevation to minimize the potential for overtopping the embankment. If an emergency spillway is not provided at a basin, then 2 feet of freeboard should be provided between the top of the embankment and the 25-year high water elevation.

A floating outlet structure (dewatering device) shall be used at all sediment basins to discharge the dry sediment storage volume over a minimum time of 72 hours; up to a maximum of 7 days. The floating outlet structure detailed on EC-STR-18 is the preferred option, with the designer selecting an orifice size located at the riser that will provide at least the minimum drawdown time for the volume of water within the dewatering zone. The outlet structure on EC-STR-18 provides a significant number of perforations along the skimmer section to maintain its function and effectiveness should some of the holes become clogged. The device is designed so as to float just beneath the water surface, removing relatively cleaner water, and allowing sediments to settle out, while avoiding floating debris that could be present on the surface.

The floating outlet structure will rise and fall with the water level and should be provided with flexible pipe and a water tight connection at the outlet riser. As the water level in the basin drops, the perforated skimmer section of the floating outlet structure should come to rest on a stone pad constructed of No. 57 stone or other suitable material. The graded top elevation of the stone pad shall be set at the same elevation as the computed “wet” sediment storage elevation, thus ensuring a permanent pool in the basin will remain allowing retained sediments to settle out.

Where additional filtration is necessary due to the presence of fine soils and clays, geotextile fabric Type III may be wrapped around the skimmer section of the floating outlet structure and attached with plastic snap ties. Where this is necessary, the designer shall specify the need for the additional geotextile wrap using a footnote to the Sediment Basin Dimensions Table (Table 10SC-10) on the EPSC plan sheet that depicts the sediment basin.

At a minimum, the length of the basin should be twice the width. This would apply in a situation in which there is only one concentrated inflow point to the basin, located on the opposite side of the basin from the outlet. In general, the distance that flows must travel from an inflow point to the outlet riser should be at least twice the width of the basin, preferably longer. A length to width ratio of 4 long to 1 wide would be considered ideal, where it is practical.

The length and width of a sediment basin may vary to conform to the specific site conditions, provided that the required volume is maintained and the length to width ratio is at least 2 long to 1 wide.

Where needed wooden baffles (or other suitable material) may be used to increase the effective flow length from the inflow point to the basin’s outlet riser. These baffles should be constructed of 4-foot by 8-foot by ¾-inch exterior plywood, type “ply-form,” grades BB, C, or ES. To the extent possible, baffles should be located mid-way between the inflow point and the outlet riser, and if possible, arranged in a manner that will provide a “meandering” flow path for the suspended particles.

When using a baffle to increase the flow length, the effective length to width ratio should be computed assuming that the pool in the basin is at the elevation of the top of the outlet riser. The following procedure may be used:

1. Determine the surface area, A, of the basin at the riser elevation.

2. Determine the effective length, L_e, from the inflow point to the outlet riser, by measuring from the inflow point to the end of the baffle, and from the end of the baffle to the riser. Examples of this computation are shown on Standard Drawing EC-STR-17.

3. The equivalent width (W_e) of the basin is normally computed by dividing the basin area by the effective flow length. That is:

$$W_e = \frac{A}{L_e}$$

The length to width ratio, in turn, would be computed as the effective flow length divided by the equivalent width. Using the equivalent length computed in step 2 and substituting the equation above yields:

$$\frac{L_e}{W_e} = \frac{L_e}{A/L_e} = \frac{L_e^{\,2}}{A} \geq 2.0$$ (preferably as high as 4.0, see above)

The emergency spillway should be constructed in a cut area whenever possible. It should also offer sufficient hydraulic capacity to convey the entire 25-year/24-hour storm event through the basin in case the principal spillway becomes clogged. Freeboard of not less than 1 foot should be provided between the crest of the emergency spillway and the design storm water storage elevation.

For earth fill embankments, a cut-off trench should be excavated along the centerline of the embankment. The trench must extend at least one foot into a stable, impervious layer of soil at the ends of the embankment and have a minimum depth of two feet. The minimum bottom width of the trench should be four feet, but it should also be wide enough to permit operation of compaction equipment. The trench side slopes should be no steeper than 1H:1V.

The side slopes of the sediment basin should be stabilized with vegetative cover. Existing vegetative cover below the proposed footprint of the embankment should be removed prior to constructing the cut-off-trench and the embankment.

Sediment basins designed according to the guidelines provided in this section should remove approximately 50% to 90% of the sediments from the runoff which enters in a large storm event. However, the removal rate may be higher for smaller storms, in particular those which do not result in significant overtopping of the outlet riser.

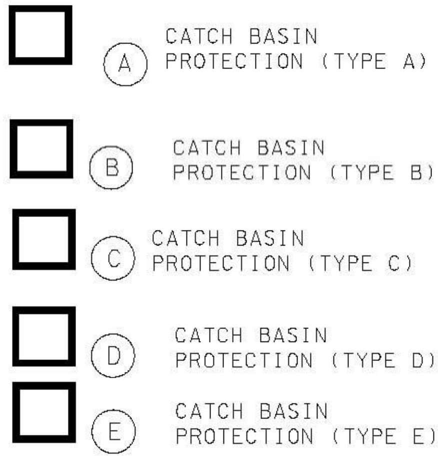
See Standard Drawings EC-STR-15 through 18 for additional details of sediment basins.

10.08.2.12.5 EXAMPLE APPLICATION

The design of a sediment basin can be a complicated process. Chapter 8 of this Manual provides additional design details as well as an example of a stormwater storage basin design.

10.08.2.13 CATCH BASIN PROTECTION (EC-STR-19)

Catch Basin Protection (Type B)



10.08.2.13.1 DEFINITION AND PURPOSE

Catch basin protection consists of a temporary structure placed around a catch basin to prevent sediment in construction site runoff from entering a storm sewer system. These structures create ponding around a stormwater inlet which allows sediments in runoff to settle out. In addition, these structures can act to filter finer sediments from the runoff before it enters the inlet. Catch basin protection may be composed of a variety of materials, including silt fence with wire backing, machined riprap Class A-1, filter sock, sediment tube, or hardware cloth and mineral aggregate (size 57).

10.08.2.13.2 APPROPRIATE APPLICATIONS

Catch basin protection should be installed around storm drain inlets which may encounter sediment laden water during construction. These measures would primarily be used in side and median ditches or in other unpaved locations. However, they may be used at curb inlets prior to the placement of pavement. Other options for catch basin and curb inlet protection are provided on EC-STR-39 and 39A, as well as EC-STR-40 through 51A. These measures are discussed in Section 10.08.2.17 and Section 10.08.2.18 respectively.

10.08.2.13.3 LIMITATIONS

None except for drainage area as specified on the Standard Drawing.

10.08.2.13.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is not required; however, the type of catch basin protection used should be limited to its maximum drainage area. At each catch basin protection the type of device should be labeled in the EPSC plans.

All catch basin protection should be constructed as shown in Standard Drawing EC-STR-19.

The maximum drainage area is 1 acre for all of the structures shown on the drawing, except for catch basin protection (Type A), which may be utilized for drainage areas up to 2 acres.

Catch basin protection (Type C) may be applied only on continuous slopes. While the remaining measures shown on the standard drawing may be applied either on continuous slopes or at sag points, they would most often be applied only at sags.

The measures installed for catch basin protection should be entrenched into the existing ground as indicated on the standard drawing. The silt fence with wire backing for catch basin protection (Type E) should be entrenched as indicated on Standard Drawing EC-STR-3C. When using sediment tubes for catch basin protection (Type D) they should be entrenched as indicated on standard drawings. EC-STR-37. Catch basin protection (Type A) and catch basin protection (Type D), when filter socks are used, do not need to be entrenched and may thus be suitable for paved areas. However, the relatively large size of catch basin protection (Type A) makes it unsuitable for areas where traffic is to be maintained.

Catch basin protection (Type A) includes a layer of mineral aggregate (size 57) on machined riprap Class A-1. These materials should be placed on geotextile fabric (Type III), and the mineral aggregate should be separated from the riprap by two layers of geotextile fabric.

Geotextile fabric (Type III) shall meet the requirements of the standard specification for geotextiles AASHTO designation M-288, Erosion Control.

The wire mesh called out for catch basin protection (Type B) and catch basin protection (Type C) should consist of at least 19 gage hardware cloth with ¼-inch mesh openings.

Catch basin protection (Type D) may make use of a stacked assembly as shown on standard drawing EC-STR-8 in order to achieve the minimum height of 18 inches when filter socks are used.

Catch basin protection shall be paid for under the following item numbers:

- 209-05, Sediment Removal, per CY
- 209-40.30, Catch Basin Protection (Type A), per Each
- 209-40.31, Catch Basin Protection (Type B), per Each
- 209-40.32, Catch Basin Protection (Type C), per Each
- 209-40.33, Catch Basin Protection (Type D), per Each
- 209-40.34, Catch Basin Protection (Type E), per Each

Payment shall include all material and labor necessary for the construction, maintenance, and removal of the catch basin protection.

10.08.2.13.5 EXAMPLE APPLICATION

Given: A rural freeway project has been designed to include a grass median which will be drained by Type 38 catch basins. The project is a mile long and the average spacing between the catch basins will be 300 feet, for a total of 17 catch basins along the project. The drainage area for each catch basin will be less than 1 acre.

Find: Determine the type of protection for the catch basins and determine the required quantities.

Solution:

Step1: Determine the type of catch basin protection: Since the Type 38 catch basin is surrounded by a concrete apron, the catch basin protection will likely be placed at least partially on a paved area. Thus, either Type A or Type D (filter sock) catch basin protection should be utilized, since these are the two types which may be placed on both paved or unpaved areas. Due to its relative ease of removal, Type D (filter sock) catch basin protection is selected for this site.

Step2: Determine the quantities: The pay items for this measure are:

<u>Item Number 209-05, Sediment Removal, per CY</u>

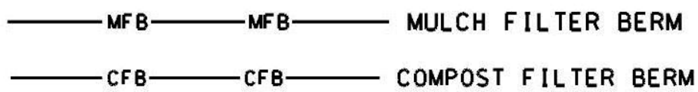
For additional details on computing Item 209-05, Sediment Removal, refer to Section 10.04.6.2.

<u>Item number 209-40.33, Catch Basin Protection, Type D, per Each</u>

Since this measure is paid for per each, the final quantity will be 17.

10.08.2.14 FILTER BERM (EC-STR-35)

Mulch Berm with Silt Fence
Location: SR-840, Williamson County, TN



10.08.2.14.1 DEFINITION AND PURPOSE

Filter berms are a linear sediment trapping device which may be used in place of silt fence to control sediment transport. Filter berms are composed of wood chips (mulch) or a 50/50 combination of wood chips and compost material. Compost can be derived from a variety of materials (called "feedstocks") and is a manufactured product which is goes through a specific heating process. This process accelerates the decomposition of the feedstock, destroys weed seeds and bacteria, and reduces the attractiveness of the material to insects.

Filter berms act first by reducing runoff flow velocities so that eroded sediments can be settled upstream of the filter. They also act to filter the runoff as it passes through the materials in the berm. This is particularly true for berms with compost, which tends to bind soil particles and other pollutants by means of chemical interaction. Recent studies have indicated that filter berms, especially compost filter berms, may be more effective at removing sediments from runoff than traditional silt fence.

10.08.2.14.2 APPROPRIATE APPLICATIONS

Filter berms may be applied on any slope along the contour where runoff can be expected to be in the form of sheet flow. Usually, this will be on slopes less than 300 feet in length or at the toe of a given slope. Filter berms may also be used where silt fence would not be feasible due to exposed rock or other conditions which would prevent the fence from being trenched in.

This sediment control BMP may be used in combination with other approved BMPs such as silt fence, silt fence with wire backing, erosion control blankets, temporary seeding, etc.

10.08.2.14.3 LIMITATIONS

When composed of properly graded materials (i.e. – particles with a good mix of sizes), filter berms can remain in place during high flow conditions, even on relatively steep slopes.

However, this measure does consist of un-compacted buoyant materials and would tend to be moved by concentrated flows. Thus, filter berms should be used only where sheet flow conditions are expected. They cannot treat flows in gullies, ditches, or channels.

10.08.2.14.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is not required; however, when filter berms are specified, the following standards should be used.

Compost is a manufactured product which should be acquired from an approved supplier. Thus, the cost of bringing this material to the job site may be a factor at some locations. Wood chips, on the other hand, can be produced on-site as a byproduct of site clearing activities. The choice of measure (mulch berm, compost berm, silt fence, etc.) to be applied at a given site should be based on the availability and relative costs of the required materials.

The drainage area upstream of a filter berm should be no greater than ¼ acre per 100 linear feet of berm. On long slopes where this limit would be exceeded, it is possible to place multiple filters, spaced as recommended in the table “Filter Berm Spacing” on the Standard Drawing. Berm spacing using the values on this table will ensure that the drainage area limit is not exceeded. Both ends of a run of filter berm should be turned up-slope to a point where the base of the berm at the terminus points will be higher than the top of the berm anywhere along the contour.

Filter berms should be trapezoidal in shape and may be installed along the contour by means of pneumatic blowers or by other suitable equipment. It is important that a berm be placed along the ground contour as they will be sensitive to failure due to concentration of flows. Runoff must be intercepted on the contour to insure that sheet flow is not converted into concentrated flow. When placed at the base of a slope, the berm should be located at least 10 feet away from the toe in order to provide an area for the storage of sediments. Filter berms should be constructed within the range of sizes indicated on the standard drawing. As a general rule, steeper slopes would require a larger berm size. In addition, the bottom width of a berm should be about twice its height.

Compost Filter Berm Installed Along Contour
Reference: Construction Site ESC BMPs for Iowa, (2003)

The material used to construct a filter berm should be well-graded as specified on the standard drawing. Usually, the particles in a berm will range in size from ¼ inch to 6 inches in length. The smaller particles serve to increase the effectiveness of the measure as a filter while the larger particles help to increase its stability under the pressure exerted by the runoff.

Filter berms should not be used alone at sites which drain directly to sensitive natural water resources such as wetlands or streams, or streams listed as Exceptional Tennessee Waters or sediment-impaired streams. At these sites, silt fence with wire backing should be used on the upstream side of the berm. The fence will prevent excessive hydraulic forces from displacing the material in the berm, while the filter berm will provide increased filtration of runoff passing through the fence.

A typical compost mix will contain “organic matter” (material derived directly from the feed stocks) combined with wood or bark chips. In order for a compost filter berm to function as required, the compost material should comply with the specifications presented on the standard drawing. In addition, the composting process should be complete (a condition called “stable”) and the material should be cured (also called “mature”) in order to ensure that no further decay will occur after the material is placed.

The material in a mulch filter berm usually will not support vegetation; therefore, these berms should not be seeded with either temporary or permanent seed. A compost filer berm will support vegetation if the material is properly graded and the portion of compost is 65% or less. Compost materials with greater percentages of organic matter usually contain more nutrients than required by the seeded grasses.

A compost filter berm which has been seeded will typically be left in place as a permanent feature, while an unvegetated compost berm or mulch filter berm can be either removed or spread on the site at the discretion of the Construction Engineer. For applications adjacent to sensitive areas, wetlands, or natural areas, it may be more practical to just leave the berm in place to decompose naturally.

Compost or mulch filter berms shall be paid for under the following item numbers:

- 209-01.30, Temporary Compost Filter Berm, per CY
- 209-01.31, Temporary Mulch Filter Berm, per CY
- 209-05, Sediment Removal, per CY

It should be noted that composted material applied as a blanket on slopes is effective at preventing erosion and may even encourage the growth of vegetation.

10.08.2.14.5 EXAMPLE APPLICATION

Given: A new embankment is to be constructed for a portion of a roadway relocation project in Sevier County. This embankment is to be 250 feet long and 10 feet high at a 6H:1V slope.

Find: Select the type of filter berm to be used at this site, determine the proposed filter berm layout and determine the required quantities.

Solution:

Step 1: Select the filter berm type: Due to the geology of the project site, it appears that there may not be sufficient topsoil to support permanent seeding on the new embankment. A check of the Qualified Products List indicates that an approved supplier of compost is located fairly nearby the project, in Knoxville. It is thus decided to use unvegetated compost berms on the site. During the project, while the berms are in place, the slope will be provided with temporary seeding. Once the project has been completed, the berms will be spread on the site in order to increase the fertility of the embankment soils and support the establishment of permanent vegetation.

Step 2: Determine the berm layout: Since the embankment will be 10 feet high at 6H:1V, the base of the slope will be 60 feet long. Accounting for the 10-foot rise, the total slope length will be 60.8 feet. 6H:1V corresponds to a 17% slope; thus, based on the Table "Filter Berm Spacing" on the standard drawing, the berms should be 25 feet apart. This represents a drainage area of much less than ¼ acre per 100 lineal feet. Thus, the first berm will be placed 25 feet from the top of the embankment; the second will be placed 50 feet from the top of the embankment and a third will be placed 10 feet away from the toe of the embankment. The distance between the second and third compost berms will be 20.8 feet.

Step 3: Compute the required quantities: The item numbers for this measure is:

<u>Item Number 209-01.30, Temporary Compost Filter Berm, per CY</u>

Because the proposed embankment slope is relatively steep (within the range of slopes shown in the table on the standard drawing), it is decided to use the maximum berm height of 3 feet. The bottom width of the berm will be twice the height, or 6 feet. Assuming that the sides of the berm will be at approximately a 1H:1V slope, the top width of the berm may be taken to be zero, and the cross sectional area may be computed as:

$$Area = 0.5 \times 6 \times 3 = 9.0 \text{ ft}^2$$

Since there will be 3 berms, each with a length of 250 feet, the total length of berm will be 750 feet. The final quantity for this item may be computed by multiplying the cross sectional area by this length and converting to cubic yards:

$$Volume = 9.0 \times 750 = 6750 \text{ ft}^3 = 250 \text{ CY}$$

<u>Item Number 209-05, Sediment Removal, per CY</u>

For additional details on computing Item 209-05, Sediment Removal, refer to Section 10.04.6.2.

10.08.2.15 SEDIMENT TUBE (EC-STR-37)

Sediment Tubes in V-Ditch Application
Reference: Colorado DOT, (2002)

TUBE**TUBE**TUBE   SEDIMENT TUBE

10.08.2.15.1 DEFINITION AND PURPOSE

Sediment tubes consist of flexible tubes of biodegradable netting filled with natural fibers or hardwood mulch. The filler material must have sufficient density to hold its shape when saturated, but must also have sufficient open space to allow water to pass through.

This measure acts first to slow flow velocities so that sediments being carried in the runoff can drop out. It also provides a filtration function as flow passes through the fibrous filler material.

10.08.2.15.2 APPROPRIATE APPLICATIONS

Sediment tubes may be utilized on slopes or in small ditches to reduce flow velocities and retain eroded sediments. While they are generally used at regular intervals on a slope, they may also be placed at the top or toe of the slope, or at breaks in grade. In addition, they may be placed on or around the perimeter of soil stockpiles or around catch basin inlets.

This measure is generally used in combination with other BMPs such as slope surface roughening, mulched seeding, etc. Additionally, because the netting, filler material, and stakes are biodegradable, the need for removal may be eliminated.

10.08.2.15.3 LIMITATIONS

This measure may not be used in a natural stream or any ditch with perennial flows.

The stability of a sediment tube is very dependent upon proper staking as shown on the standard drawing. Thus, they may not be utilized on pavement, rocky soil or at any location where the stakes cannot be driven to the required depth.

Sediment tubes can become heavy and may be difficult to move once they have been saturated.

10.08.2.15.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is not required; however, when sediment tubes are specified they should be shown in the EPSC plans according to EC-STR-37. At each location sediment tubes are used their size should be labeled in the EPSC plans.

A list of acceptable filler material for a sediment tube is provided on the standard drawing. When straw is utilized, the material should be certified as free of weed seeds. The tube should be placed a minimum of 2 inches deep in a trench that is free of stones or other materials which would prevent good contact between the tube and the ground surface. This is necessary to ensure that the tube will not be undercut.

When applied on slopes, sediment tubes ranging from 8 to 24 inches in diameter should be placed along the contour, and the ends of the tubes should be turned upslope in order to prevent erosion which could occur as flow bypasses around the ends of the row. This will force the discharge to overtop the tubes away from the end points. The spacing between rows of tubes should be based on the table “Sediment Tube Spacing Table for Slope Application” on the standard drawing. In general, for slope applications, the maximum drainage area should be ¼ acre per 100 linear foot of tube.

The size of a sediment tube for a slope application should be selected based on the gradient and length of the slope. In general, larger tube diameters should be selected for steeper or longer slopes.

Where long rows are required on a slope, the ends of the individual tube segments should be overlapped a minimum of 24 inches as shown on the standard drawing. This will ensure that gaps will not occur between individual tube segments, allowing sediment laden water to escape the measure.

Removal is not necessary for sediment tubes which have been placed on slopes. Rather, they may be left in place to decompose over time.

When applied in a ditch, the tube should extend on the sides to a height equal to 3 feet plus the diameter of the tube, or to the top of the ditch, whichever is less. This will ensure that the ends of the tube will not be overtopped during the design storm event (see Section 10.05.1). This criteria is essential to minimize the potential for the water to flow around the ends of the measure prior to overtopping at the center. Typically, an individual tube segment will not be sufficiently long to meet this criteria. Where joints are necessary within the ditch, it will be necessary to provide a second row of sediment tube with the joints staggered by a distance equal to half of the individual segment length as shown on the Standard Drawing. The staking and arrangement of the joints should be as shown on the standard drawing.

The minimum diameter for any sediment tube applied in a ditch should be 20 inches. This will ensure that the tube will function effectively as a velocity control device, allowing sediment to drop out of the flow.

At sites which drain to Exceptional Tennessee Waters or sediment-impaired streams, the maximum drainage area to any given sediment tube should be no more than 10 acres. At all other sites, the maximum drainage area may be increased to 15 acres.

In ditch applications, the spacing between sediment tubes should be based on the table "Sediment Tube Spacing Table for Ditch Application" on the standard drawing.

Sediment tubes applied in ditches should be removed once they are no longer needed.

Sediment tubes shall be paid for under the following item numbers:

- 209-05, Sediment Removal, per CY
- 740-11.01, Temporary Sediment Tube, (8 inch), per LF
- 740-11.02, Temporary Sediment Tube, (12 inch), per LF
- 740-11.03, Temporary Sediment Tube, (18 inch), per LF
- 740-11.04, Temporary Sediment Tube, (20 inch), per LF
- 740-11.05, Temporary Sediment Tube, (24 inch), per LF

Sediment tubes are designed to be biodegradable. Thus, it may be necessary to take into account the expected life span of the measure when calculating quantities for a long-duration project. If the filler material for a sediment tube is to be wheat straw, or if it is unknown, the quantity estimate should be based on a life span of 12 months. Tubes filled with other materials may be assumed to have a life span of 18 months. Projects exceeding this duration may require a complete replacement and re-measurement of the material. In addition, the staging of the Erosion Prevention and Sediment Control plan should be considered in computing the quantity. The computations would thus take the following form:

$$\frac{Calendar\ Days\left(accounting\ \ for\ EPSC\ Plan\ Phases\right)}{\left(Life\ span\ in\ months\right)\times\left(30\ days\right)} = Adjustment\ \ factor$$

The adjustment factor should be rounded to nearest whole number. The final quantity may then be computed from:

$$Computed\ Linear\ Feet\ of\ Sediment\ Tube \times Adjustment\ Factor = Total\ Quantity, LF$$

10.08.2.15.5 EXAMPLE APPLICATION

Given: A proposed roadway project is to include a cut slope 15 feet high and 200 feet long at a 3H:1V slope. A roadside ditch will be located at the toe of this slope. This ditch will have a 4-foot bottom width, and a 6H:1V side slope adjacent to the roadway. It will also be 2.5 feet deep. Past the cut slope, the ditch is proposed to extend an additional 500 feet at a slope of 1%. Sediment tubes are to be provided for sediment control at this site.

Find: Determine the quantities of sediment tubes required.

Solution:

Step 1: Determine the slope length: Since the slope will be 15 feet high at a 3H:1V slope, it will cover a horizontal distance of 45 feet. Thus, the slope length may be calculated as:

$$Slope\ Length = \sqrt{15^2 + 45^2} = 47.4 \text{ feet}$$

Step 2: Determine the quantity of sediment tube required on the cut slope: Since the slope is not extremely long and only moderately steep, it is judged that 8-inch diameter sediment tubes may be used. Because the existing ground drains toward the cut slope, a row of sediment tubes will be placed at the top. In addition, a row of sediment tubes will be placed near the bottom of the cut slope, at the top of the proposed lining for the roadway ditch. Since the ditch will have a vertical depth of 2.5 feet, the length of the proposed lining along the 3H:1V slope will be 7.9 feet. Thus, the total slope length to be protected above the ditch lining will be 39.5 feet. Based on the table “Sediment Tube Spacing Table for Slope Application” on the standard drawing, the maximum allowable spacing between rows of tubes should be 15 feet. In order to meet this requirement, it will be necessary to add two rows of sediment tubes between the top and bottom rows, which results 4 rows spaced at 9.9 feet.

Information from the vendor indicates that 8-inch diameter sediment tubes will be available in 25-foot segments. Since adjoining segments must be overlapped by 2 feet, the number of segments, N, in a 200-foot length may be computed by:

$$25N - (N-1)2 = 200 \text{ feet}$$

Solving this expression yields a value of 8.78 for N, which is rounded to 9. Nine segments at 25 feet each, yields a total length of 225 LF for each row of 8-inch diameter tube. However, due to the overlap between segments, this is not equal to the installed length. The installed length for 9 segments would be equal to:

$$Installed\ \ Length = 25(9) - (9-1)(2) = 209 \text{ feet}$$

This installed length would leave 4.5 feet at each end of the row to be turned upslope to prevent flows from bypassing, and this is judged to be reasonable. Thus, the final quantity of 8-inch diameter sediment tube on the slope would be 4 times 225 feet, or 900 LF.

Upon consideration, the design specified above seems to be excessive. A spacing of 9.9 feet between rows appears to be overly-conservative, given that a spacing of up to 15 feet would be allowed. On the other hand, eliminating a row would result in 3 rows spaced at 19.8 feet, which exceeds the maximum spacing. While it would not be acceptable to specify the minimum tube size of 8 inches for this situation, it is judged that increasing the tube diameter to 18-inches may be sufficient to compensate for the greater row spacing. Thus, an alternative design is considered using 3 rows of 18-inch diameter tube.

Vendor information indicates that 18-inch diameter sediment tubes are available only in 10-foot lengths. Writing the same expression as was used above, it is found that “N” for a 10-foot segment length would be 25.25, which is rounded up to 26. Thus, a total length of 260 feet would be required for a single row, and the total quantity for 3 rows would be 780 LF. Although this results in a smaller final quantity, the cost per lineal foot for the 18-inch diameter tube is greater than the cost for the 8-inch diameter tube, and the smaller diameter is found to be more cost-effective. Thus, 4 rows of 8-inch diameter tube is selected as the design configuration.

<u>Item Number 740-11.01, Temporary Sediment Tube, (8 inch), per LF</u>

As discussed above, the final quantity for this item will be 900 LF.

Step 3: Determine the quantity of sediment tube required in the roadside ditch: The total length of the ditch will be 700 feet. Based on the table "Sediment Tube Spacing Table for Ditch Application" on the standard drawing, the maximum allowable spacing between rows of tubes for a ditch at a 1% slope should be 150 feet. Dividing the 700-foot length of the ditch by 150 feet yields a result of 4.7, which is rounded up to 5 rows of sediment tubes spaced at 140 feet.

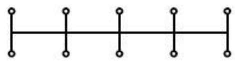
As discussed above, the height of the ditch will be 2.5 feet. Since the side of the ditch adjacent to the cut slope will be at a 3H:1V slope, the slope length on that side of the ditch will be 7.9 feet. The other side of the ditch will be at a 6H:1V slope, which yields a length along the slope of 15.2 feet. Thus, the total length along the perimeter of the 2.5-foot deep ditch will be:

$$Perimeter = 7.9 + 4.0 + 15.2 = 27.1 \text{ feet}$$

Item Number 740-11.04, Temporary Sediment Tube, (20 inch), per LF

Since the ditch is 2.5 feet deep, it necessary to extend the sediment tubes only to the top of the ditch bank. Based on vendor data, 20-inch sediment tubes are supplied in 10-foot lengths. Thus, the 27-foot perimeter of the ditch can be covered by 3 segments of tube. Since two additional tubes will be required for each row in order to reinforce the joints, as shown on the standard drawing, the total length of tube required for each installation will be 50 LF. For a total of 5 rows, the final quantity for this item would be 250 LF.

10.08.2.16 FLOATING TURBIDITY CURTAIN (EC-STR-38)



Floating Turbidity Curtain
Used at Bridge Crossing
Reference: North Carolina DOT

10.08.2.16.1 DEFINITION AND PURPOSE

Floating turbidity curtains are an in-stream sediment control measure designed to trap or filter sediment; not halt the movement of the water, itself. This device consists of a filter fabric curtain suspended from floats and held vertically in the water by means of a bottom ballast chain. This measure is placed around a construction site located either adjacent to, or within a water body, to provide an isolated work zone where sediments generated by the project can settle. In this way, it prevents the migration of these sediments into the larger remaining water body.

10.08.2.16.2 APPROPRIATE APPLICATIONS

Floating turbidity curtains may be applied adjacent to the shoreline of a river or lake to contain sediments which may be carried into the water by construction site runoff. They should be considered only where adequate or conventional on-shore sediment control measures are not feasible or possible. They may also be used to surround a work site within the channel of a river (i.e. bridge pier construction, dredging or filling) or within a larger water body in order to prevent worksite sediments from being dispersed.

10.08.2.16.3 LIMITATIONS

This measure should *not* be applied where the anticipated flow velocities will exceed 5 feet per second. Turbidity curtains are *not* designed as prefabricated dams; and therefore, should not be used across flowing streams.

In ponds and lakes, large changes in stage can cause the curtain to become submerged or to be damaged. This measure is best applied in situations or during periods of time when anticipated changes in the water surface elevation will be minimal. Also, wave action from boats or wind can significantly reduce the effectiveness of a floating turbidity curtain.

10.08.2.16.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is not required; however, when floating turbidity curtains are specified, the following standards should be used.

A floating turbidity curtain consists of a geotextile filter cloth with sufficient permeability to allow flow to pass through while retaining sediments. The cloth is suspended from floats which are anchored into place to maintain the shape and location of the barrier. A ballast chain is included in a pocket at the bottom of the curtain to help hold the cloth in a vertical position and to provide tensile strength when the material is stressed.

The curtain is formed by joining segments of geotextile fabric which are 50 to 100 feet long, and an anchor (consisting of two weights, cables and floats) should be placed at each joint in the fabric. Additional anchors may be utilized, depending upon the anticipated flow velocities or wave action, based on manufacturer recommendations. At a minimum, each end of the curtain should be provided with an on-shore anchor and two anchors would be required in the water.

In most situations, the bottom of the curtain should be approximately 12 inches above the bottom of the lake or river. This will prevent the bottom of the curtain from being buried by retained sediments, and in turn, reduce the quantity of sediment released into the water when the curtain is removed. Additionally, movement of the curtain over the bottom of the water body due to wind or wave action on the flotation system would stir or fan sediments already settled out. In situations where significant wave action is anticipated, either as the result of wind or boat traffic, the depth of the curtain should be no greater than 12 feet. This will prevent stresses in the fabric from becoming excessive as it billows with the force of the waves.

The curtain should be located as close as possible to the project, while allowing sufficient room for any equipment which must work in or near the water.

When applied in a river, a floating turbidity curtain should be installed parallel to the shore such that it would not intercept the main force of the current. A curtain should not be placed across (perpendicular to) a flowing water body.

The designer should consider the morphology of the river in evaluating the anticipated flow velocities at a proposed turbidity curtain site. Where a river runs a straight course, flow velocities adjacent to shore are usually much lower than the velocities in the center of the channel. On the other hand, flow velocities can be very high on the outside of a bend in the river.

Proper consideration should be given to safety measures at locations where boat traffic may be present. Usually, this is addressed by providing floats with a bright yellow or orange color and by providing lighted marker buoys for night time use. The U.S. Coast Guard, Corps of Engineers, TVA, or other regulating agency may require the use of lighted buoys on navigable waterways.

Floating turbidity curtains should be indicated on the EPSC plans by showing the proposed location of the curtain with cross bars placed at the required anchor locations. Other aspects of the curtain design, including the need for additional anchors, should be determined by the contractor, working with the supplier.

In shallow water (2 feet of depth or less) a turbidity curtain may be installed on stakes driven into the bed of the water body. For obvious reasons, a turbidity curtain will not be practical where conditions are very shallow and bedrock exists on the channel bottom.

Quantities for floating turbidity curtain should be calculated by increasing the straight-line length of the curtain by 10% to 20%. This will allow for measuring errors and allows for wave action during high winds and higher than expected water surface elevations.

Floating Turbidity Curtain shall be paid for under the following item numbers:

- 209-13.04, Turbidity Curtain, (description), per LF
- 209-13.05, Turbidity Curtain, (description), per LF
- 209-13.06, Turbidity Curtain, (description), per LF
- 209-13.07, Turbidity Curtain, (description), per LF
- 209-13.08, Turbidity Curtain, (description), per LF

The multiple item numbers available for this measure allow for different types of turbidity curtain to be specified on a single project. Because of the possibilities for variation in the design (with or without lighted buoys, for example), the standard drawing does not specify standard types of curtain. Rather, the designer must provide a brief statement to substitute for "description" in the pay items list. This brief statement should be included in the call-out for the turbidity curtain shown on the EPSC Plan sheets.

10.08.2.16.5 EXAMPLE APPLICATION

Given: A 400-foot reach of the Cumberland River runs parallel to a highway in Davidson County. The channel of the river has been meandering toward the highway and has begun to threaten the stability of the roadway embankment. Because of this, it has been proposed to install hard armoring on the bank to prevent further migration. Since the eroded bank is immediately adjacent to the water, it will not be possible to utilize on-shore sediment control measures. Thus, it is proposed to utilize a floating turbidity curtain to minimize the release of sediments into the river.

Find: Determine the type and quantity of floating turbidity curtain required.

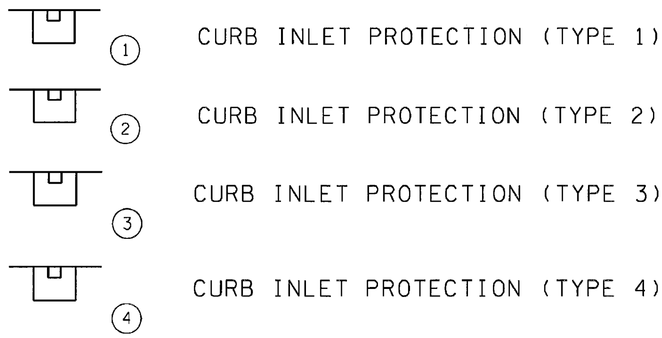
Solution: This reach of the Cumberland River is navigable and is regularly used for barge traffic. Therefore, lighted buoys will be required at each anchor point and the pay item for this measure will be:

<u>Item Number 209-13.04, Floating Turbidity Curtain, (with Lighted Buoys), per LF</u>

Although the length of the threatened area is 400 feet, an additional 100 feet will be required for the construction of an access road. Thus, the turbidity curtain will have to cover a total length of 500 lineal feet. In order to provide adequate room for the equipment to work, the curtain will be placed 20 feet from the edge of water. Thus, an extra 40 feet of length is allowed at each end of the curtain in order to tie the measure to the on-shore anchors, which results in a total straight-line distance of 580 lineal feet. This length is increased by 20% to yield a final quantity of 700 LF.

This installation will be represented on the EPSC plan sheets as a line in the river 500 feet long with 40-foot diagonal lines at each end. The diagonal lines will be tied to anchors on shore. The 500-foot length of curtain in the water will be marked with 6 cross bars spaced at 100 feet each in order to represent the in-water anchors. This installation will be along the outside of the bend in the river, and will be subject to wave action from passing barges and other small watercraft. Thus, it represents a severe application for this measure. However, the need for additional anchors will be determined by the contractor.

10.08.2.17 CURB INLET PROTECTION TYPES 1, 2, 3, AND 4 (EC-STR-39 & 39A)



Curb Inlet Protection Type 4
Reference: Department of Civil, Construction, and Environmental Engineering, Iowa State University

10.08.2.17.1 DEFINITION AND PURPOSE

These measures consist of structures placed on or around an existing or new curb inlet to reduce the quantity of sediment which might enter the storm drainage system during construction. Prior to the stabilization of the project construction site, there is a potential for significant amounts of sediment to enter the storm sewer system. In extreme cases, the storm sewers could become clogged and lose a large portion of their capacity. Curb inlet protection is intended to minimize this problem by reducing the quantity of sediments which could be washed into the curb inlets. These measures accomplish this by slowing flow velocities upstream of the inlet so that sediments can drop out. Some of these measures also provide a filtration capacity.

Detailed descriptions of the materials used in each type of curb inlet protection listed are provided in the Planning and Design Criteria.

10.08.2.17.2 APPROPRIATE APPLICATIONS

These measures may be applied at existing or new catch basin curb inlets once the grate and frame have been installed and the asphalt or concrete roadway surface has been placed, but areas up-grade of the inlet are not stabilized. Curb inlet protection is designed to operate effectively without the need for stakes or excavated trenches. Curb inlet protection may be used for both inlets on grade or for inlets in a sag by selection of the appropriate type.

10.08.2.17.3 LIMITATIONS

Curb inlet protection usually creates a significant amount of ponding and should be applied only where ponded water will not create problems. Because of this, they are best utilized at locations where the traffic volume and travel speed is low.

These measures should be applied as secondary sediment control devices. That is, they should be used in conjunction with other upstream EPSC measures. Further, these measures are not typically effective at removing small silt or clay-sized particles from the flow.

These measures normally require a higher level of maintenance compared to other BMPs, as sediment removal may be required after each rainfall event. Further, the stone or fabric materials used in these measures can quickly become clogged with sediment, and thus require frequent replacement or cleaning. The size and slope of the disturbed area, the amount of additional upstream EPSC measures, and the presence of soil stabilization upstream of this measure will all influence the amount of maintenance required for this BMP to perform.

10.08.2.17.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is not required; however, the type of curb inlet protection used should be limited to its maximum drainage area. At each curb inlet protection the type of device should be labeled on the EPSC plans.

The maximum allowable drainage area for any type of curb inlet protection is 1 acre.

One of the important factors in the selection of curb inlet protection type is the level of ponding it may create. The designer should consider not only the depth of ponding which may occur, but also, where the runoff will go if it bypasses the inlet or overtops the curb. This could affect a variety of issues including:

- construction difficulties created by ponded water or saturated soils
- saturation of roadway sub-base
- ponding on adjacent properties
- difficulties implementing the traffic control plan
- existing traffic on an open roadway

The consideration of ponding depth is particularly important in roadway fill sections where flows overtopping the curb may create rill or gully erosion on the fill slope or affect areas adjacent to the roadway. Excessive ponding can be minimized by providing the spillways and weirs as shown on the standard drawings.

Each type of curb inlet protection utilizes different types of materials and has unique characteristics. Thus, information specific to each type is discussed below:

Curb Inlet Protection Type 1: This measure consists of a single row of concrete masonry units placed lengthwise on their sides around the perimeter of the inlet so that the holes are in a horizontal position. The exterior faces of the blocks are lined with hardware cloth in order to retain the coarse aggregate (size 57) which is placed around the structure. This measure acts by slowing flow velocities in the curb, allowing sediments to drop out. The coarse aggregate also provides an additional filtration capacity for coarse-grained sediments.

Curb Inlet Protection Type 1 is usually applied at sags. It should be noted that the typical concrete masonry unit is 7 ½ to 8 inches high, which is greater than the typical curb height. Thus, any flow which cannot be conveyed through the coarse aggregate may overtop the curb. Since flow rates through the stone can be quite low, particularly when it is clogged with sediment, the designer should assume that this measure will cause overtopping. On the other hand, once the curb has been overtopped, the area available to pass water into the inlet is comparatively large so that the depth of ponding should not be significantly greater than the top of the curb.

Type 1 Curb Inlet Protection Type 1 (Block and Gravel)
Reference: International Erosion Control Association Photo Gallery, (2001)

Curb Inlet Protection Type 2: This device consists of two rows of sandbags (or bags filled with size 57 stone) stacked together to form a small dam. When applied for an inlet on grade, the dam is placed just upstream of the grate, on a curved alignment, forming a j-hook shape, which extends about three feet from the curb. A single sandbag is omitted from the upper row in order to form a small spillway. When this measure is applied at roadway sags, the dam surrounds the inlet, with one bag omitted from the upper row on each side to form separate spillways. In order to minimize the direct release of sediment laden runoff into the inlet, the spillways should not be located immediately adjacent to the curb. Where possible, the spillway should be approximately 1 inch below the top of the curb. This will help reduce the possibility that the curb will be overtopped.

The sandbags or gravel-filled bags used to form the dam should be tightly packed. Where this is not possible, the measure can be supplemented by placing a layer of geotextile fabric on the upstream face of the dam and filling in with coarse aggregate (size 57). This may also be used where a significant quantity of silt or clay particles are anticipated due to localized soil characteristics.

Curb Inlet Protection Type 2 functions primarily by slowing upstream flow velocities so that sediments can drop out. However, the Type 2 device may create ponding depths which are somewhat lower than Type 1 or Type 3 inlet protection, and so, may not be as effective for this purpose in larger rainfall events. Additionally, the sandbags should be considered *not* to provide any filtration capacity.

Curb Inlet Protection Type 3: This device consists of a wooden frame of 2 x 4’s placed over the curb iron, to which a sheet of hardware cloth has been attached. The hardware cloth is extended from the curb a distance sufficient to cover the grate and is then covered with a wedge of coarse aggregate (size 57). This measure acts by slowing flow velocities in the curb, allowing sediments to drop out. The coarse aggregate also provides an additional filtration capacity for coarse-grained sediments.

Curb Inlet Protection Type 3
Reference: OHIO Department of Natural Resources, (2005)

Curb Inlet Protection Type 3 may be applied either at sags or at inlets on grade. While this device has the advantage of being a relatively compact installation, its overflow consists of a slot only as wide as a 2 x 4 (1.5 inches), which will not accept flow until the curb has been, or is being overtopped. Thus, when this measure is applied in a roadway sag, the designer should expect that the ponded water will be higher than the curb, possibly by several inches. At inlets on grade, this limited overflow capacity may result in large amounts of bypass flow. Because this bypass has the potential to wash out the coarse aggregate, this device should not be applied where the longitudinal slope of the curb and gutter exceeds 1%. Type 3 Curb Inlet Protection should also not be specified at locations where a significant sediment load in the runoff would cause the coarse aggregate to quickly become clogged.

Curb Inlet Protection Type 4: This device is formed by wrapping a continuous piece of geotextile fabric around an inlets grate before installing (or re-installing for existing inlets) the grate. At the back of grate, on top, the fabric is attached to a pressure treated 2 x 4 with wire staples which is then placed in the gutter line above the grate. The Type 4 device acts by filtering the runoff as it enters the inlet.

Curb Inlet Protection Type 4 may be applied either at sags or at inlets on grade. It does not significantly obstruct flows in the gutter and thus should not cause ponding when applied at inlets on grade. However, flow rates through the fabric will be reduced, even when the fabric is clean, and will become even lower once the fabric has been clogged with sediment. Thus, it should be anticipated that most of the flow at an inlet on grade will bypass, especially where flow velocities are high due to the longitudinal slope. The designer should consider whether the gutter will have sufficient capacity to convey these bypassed flows in the storm event used to design the EPSC measures (see Section 10.05.1). Because the 2 x 4 placed on the inlet obstructs a significant amount of the opening area of the curb iron, the overflow area provided by this measure can be quite small. Thus, the ponding depths created by this measure at a roadway sag point may easily overtop the curb.

Curb Inlet Protection shall be paid for under the following item numbers:

- 209-05, Sediment Removal, per CY
- 209-09.40, Curb Inlet Protection, (Type 1), per Each
- 209-09.41, Curb Inlet Protection, (Type 2), per Each
- 209-09.42, Curb Inlet Protection, (Type 3), per Each
- 209-09.43, Curb Inlet Protection, (Type 4), per Each

Payment shall include all material and labor necessary for the construction, maintenance, and removal of the curb inlet protection.

10.08.2.17.5 EXAMPLE APPLICATION

Given: A pavement replacement project with new storm sewers is proposed for a 1-mile section of urban roadway in Knoxville. A stream crosses the roadway at about the middle of the project area and the profile grade consists of a single sag with the low point at the stream crossing. The maximum longitudinal grade is 0.85%. West of the stream, the roadway will be in a cut section, while east of the stream it will in a fill section. The traffic control plan is to detour traffic around the project site.

The proposed storm sewers will include 10 catch basins. On each side of the roadway, two catch basins will be in the cut section, two will be in the fill section and one will be at the sag point. The catch basins at the sag point will be located almost directly on top of the cross drain. Because the drainage areas at all of the catch basins will be less than 1 acre, it is proposed to use curb inlet protection at each of the inlets.

Find: Determine the types and quantities for the curb inlet protection to be used for this project.

Solution: The selection of curb inlet protection type should be based upon consideration of the site conditions. In the western half of the project, off-site flows will enter the roadway so that gutter flows in this area will be somewhat greater than the flows in the eastern half of the project. Significant levels of ponding on the road are judged not to be a serious issue in this area since water overtopping the curbs will still be contained within the project limits and traffic has been routed around the site. Thus, Type 3 curb inlet protection is proposed for the 4 inlets west of the stream. Because this measure creates deeper ponding levels than the other types, it also provides the most velocity reduction, which is desired due to the higher flow rates. It should be noted that these devices are feasible only because the longitudinal slope is less than 1%. Had the profile grade been steeper than 1%, it would have been necessary to specify Curb Inlet Protection Type 2 in this area.

As noted above, the eastern half of the project is in a fill section. Because the existing ground past the toe of the fill slopes away from the project on both sides, it is necessary to ensure that the curbs will not be overtopped by the inlet protection. Due to the mild longitudinal slope, it is anticipated that flow velocities will also be moderate. Thus, Type 4 inlet protection is selected for this area in order to minimize the possibility that the curbs will be overtopped.

At the sag points, Curb Inlet Protection Type 1 is chosen for these inlets. This type is desired in order to prevent sediments from collecting on the inlet at this location.

The pay items for curb inlet protection for this project will be:

Item Number 209-09.40, Curb Inlet Protection, (Type 1), per Each

The final quantity for this item will be 2.

Item Number 209-09.42, Curb Inlet Protection, (Type 3), per Each

The final quantity for this item will be 4.

Item Number 209-09.43, Curb Inlet Protection, (Type 4), per Each

The final quantity for this item will be 4.

Item Number 209-05, Sediment Removal, per CY

For additional details on computing Item 209-05, Sediment Removal, refer to Section 10.04.6.2.

10.08.2.18 CATCH BASIN FILTER ASSEMBLIES (EC-STR-40 THROUGH 51A)

Catch Basin Filter Assembly on Inlet
Location: SR-840, Williamson County, TN (2004)

10.08.2.18.1 DEFINITION AND PURPOSE

Catch basin filter assemblies consist of a frame built from treated lumber which has been covered with hardware cloth and geotextile fabric. These structures are placed over active catch basins and act to filter suspended solids from stormwater runoff before it can enter the storm drainage system. Because the filter fabric covers the entire frame and is trenched into the ground, it serves to completely isolate the catch basin. These structures can also slow stormwater flow velocities in order to all sediments to settle. Catch basin filter assemblies provide a large geotextile surface area in order to maximize the quantity of inflow that can be achieved for a given head on the inlet.

10.08.2.18.2 APPROPRIATE APPLICATIONS

Catch basin filter assemblies should be used where interception of concentrated flows (e.g. ditches and swales) is required after the catch basin is constructed but prior to establishing vegetation. While the filter assembly frames are designed to fit square or rectangular catch basin structures, they may also be utilized with round catch basins.

Once a filter assembly has been removed from a finally stabilized site, the wooden frame may be reused at another site or on another project.

10.08.2.18.3 LIMITATIONS

Placement of a filter assembly on a catch basin may decrease the hydraulic capacity of the inlet. Careful maintenance of the filters is crucial to ensure that they function properly.

These structures should be used only where an adequate area for localized pooling of water exists.

The larger filter assemblies can be quite heavy, and substantial effort may be required to place or move them.

10.08.2.18.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is not required; however, the maximum discharge for each catch basin filter assembly should be checked based the maximum ponding depth at each location. At each catch basin filter assembly the type of device should be labeled in the EPSC plans.

Catch basin filter assemblies are constructed of filter fabric and hardware cloth over a pressure treated lumber frame. The fabric should be trenched in and secured with stone along the four sides of the base. Clogged or damaged fabric may be replaced and the lumber frame reused.

The various types of catch basin filter assemblies are designed to fit specific types of catch basin, as shown in Table 10SC-11.

Filter Assembly Type	Catch Basin Types*	Catch Basin Size
1	12LP, 25LP, 28LP, 38S, 41LP, 42S	4 feet square
2	10SB, 12SB, 25SB, 38SB, 39S, 41SB, 42SB	5 feet, 4 inches square or 48 inches round
3	12SC, 25SC, 38SC, 39SC, 41SC, 42SC, 51SC	6 feet, 6 inches square or 60 inches round
4	12SD, 25SD, 31SD, 39SD, 41SD, 42SD,51SD	8 feet, 4 inches square or 72 / 84 inches round
5	12SE, 14SE, 25SE, 31SE, 39SE, 41SE, 46SE	10 feet, 8 inches square or 96 / 108 inches round
6	10S, 12B, 12P, 12S, 13B, 13P, 13S, 25B, 25P, 25S, 28B, 28P, 28S, 41P, 41S	5 feet, 4 inches by 4 feet, 4 inches
7	14B, 14P, 14S, 26P, 26S, 26P, 29S	9 feet, 4 inches by 4 feet, 4 inches
8	16B, 16S, 27S, 40S, 43SB, 45S	9 feet, 4 inches by 5 feet, 4 inches
9	17S, 43SC	9 feet, 4 inches by 6 feet, 6 inches
10	Special (132 inches by 132 inches)	13 feet square
11	Special (144 inches by 48 inches)	13 feet, 4 inches by 5 feet, 4 inches

Table 10SC-11
Summary of Catch Basin Filter Assembly Types
* See Chapter 7 for a detailed description of the catch basin types listed.

Standard Drawing EC-STR-40 describes the use of catch basin filter assemblies for round catch basins. Each of the standard drawings from EC-STR-41 through EC-STR-51 details a specific type (i.e. – size) of filter assembly.

Table 10SC-12 specifies the maximum discharges which may be accommodated by a filter assembly. The peak discharge generated at the catch basin site by the storm event specified in Section 10.05.1 should be less than or equal to the value shown in the table.

Filter Assembly Type	Allowable Peak Discharge (cfs)
1	10
2	13
3	15
4	19
5	24
6	12
7	16
8	17
9	18
10	30
11	21

Table 10SC-12
Allowable Peak Discharges for Various Filter Assembly Types
Assumes 1.5 feet of head on the filter and a 50% clogging factor

When specifying the use of catch basin filter assemblies, careful consideration should be given to upstream constraints on the allowable ponding depth. The allowable discharges provided on Table 10SC-12 may need to be adjusted if the allowable ponding depth is less than 1.5 feet. This is especially important when specifying filters for catch basin inlets located on a long, sloped median.

When utilizing these filters for multiple inlets on a continuous slope, it may be necessary to provide some temporary means of pooling the water around the filter assembly in order to minimize the amount of flow which would bypass. This will help to maximize the flow captured by an inlet on grade and help to prevent flows at the most downstream catch basin from becoming excessive. This may be accomplished by means of rock check dams placed immediately downstream of the filters, provided that the check dams are designed according to Section 10.08.1.

Where the flow rates at a catch basin site exceed the maximum values presented in Table 10SC-12, an alternate type of sediment-control BMP should be considered.

Catch basin filter assemblies shall be paid for under the following item numbers:

- 209-05, Sediment Removal, per CY
- 209-40.41, Catch Basin Filter Assembly (Type 1), per Each
- 209-40.42, Catch Basin Filter Assembly (Type 2), per Each
- 209-40.43, Catch Basin Filter Assembly (Type 3), per Each
- 209-40.44, Catch Basin Filter Assembly (Type 4), per Each
- 209-40.45, Catch Basin Filter Assembly (Type 5), per Each
- 209-40.46, Catch Basin Filter Assembly (Type 6), per Each
- 209-40.47, Catch Basin Filter Assembly (Type 7), per Each
- 209-40.48, Catch Basin Filter Assembly (Type 8), per Each
- 209-40.49, Catch Basin Filter Assembly (Type 9), per Each
- 209-40.50, Catch Basin Filter Assembly (Type 10), per Each
- 209-40.51, Catch Basin Filter Assembly (Type 11), per Each

The computation of quantities for catch basin filter assemblies should be based on the number and types of catch basins to be protected. An adjustment should not be made for the reuse of wooden frames at more than one catch basin site, even when the project will be phased due to the large area to be disturbed.

10.08.2.18.5 EXAMPLE APPLICATION

Given: A Type 38S catch basin is to be located adjacent to a freeway median cross over. The inlet will collect runoff from an area of 1.912 acres, which ultimately drains to a known Exceptional Tennessee Water. Rational method computations for the design of the storm drainage system indicate that the runoff coefficient at this site is 0.6 and that the 5-year rainfall intensity is 6.3 inches per hour. In order to ensure that the roadway sub-base will be properly drained, the maximum allowable ponding depth at the site is 1.2 feet. Due to the sensitive nature of the receiving stream, a catch basin filter assembly is desired for this site in order to ensure the greatest possible filtration of sediments.

Find: Determine the type of catch basin filter assembly required for this site and check to ensure that the depth of ponded water will be less than allowable.

Solution: Based on Table 10SC-12, a Type 1 catch basin filter assembly is selected for this site. In order to check the depth of ponding which would occur in the 5-year storm, it is necessary to compute the peak discharge, using the Rational Method:

$$Q = CiA = (0.6)(6.3)(1.912) = 7.23 \text{ cfs}$$

The maximum allowable flow rate at a Type 1 catch basin filter assembly for a ponding depth of 18 inches is shown in Table 10SC-12 to be 10 cfs. Since the flow through the filter fabric on the assembly essentially corresponds to flow through a porous media, it is possible to estimate the ponding depth associated with 7.23 cfs simply by taking the ratio of the flow rates. Thus:

$$Ponding\ Depth = \frac{7.23}{10} \times 1.5 = 1.1 \text{ feet}$$

Since the ponding depth at the 5-year flow rate will be less than 1.2 feet, the catch basin filter assembly may be used at this site.

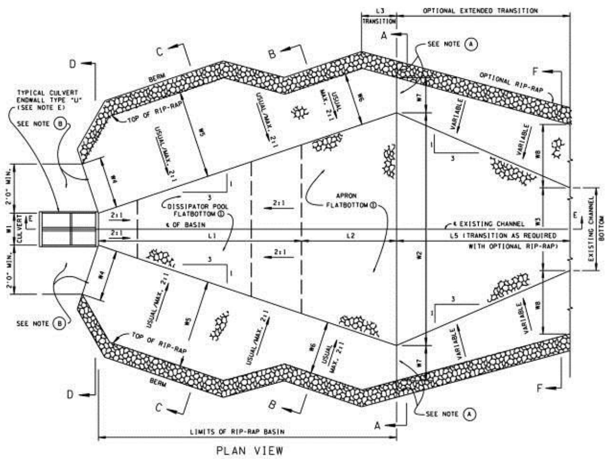
10.08.3 FLOW CONTROL MEASURES

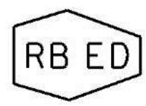
Roadway construction or other projects can potentially have significant impacts on the flow regime of a waterway. These projects can introduce points of concentrated, high-velocity flows, such as at a culvert outfall. They can also increase the flow rate in a waterway by adding impervious area to the watershed or by channeling previously dispersed flows. These impacts can lead to increased erosion and sedimentation in a waterway.

The BMPs described in this section are intended to minimize the potential for these impacts by controlling either the quantity or the velocity of flow in a channel. These measures are usually permanent structural features, which distinguishes them from the temporary measures presented in the previous two sections. This section describes a number of flow control BMPs which may be used on TDOT projects. It also provides guidelines on where and how to apply these practices.

It should be noted that temporary diversion berms may be considered flow control BMPs because they are often used to divert flows from a sloping area to an erosion-resistant outlet or away from another area of the project. This measure is discussed in detail in Section 10.08.1.7; and thus, is not addressed further in this section.

10.08.3.1 PERMANENT RIPRAP ENERGY DISSIPATOR (EC-STR-21)





PERMANENT RIPRAP
ENERGY DISSIPATOR

Permanent Riprap Energy Dissipator
(Photo not currently available)

10.08.3.1.1 DEFINITION AND PURPOSE

This measure consists of a constructed riprap basin composed of a flat bottom pool and an apron. These structures should be considered permanent, and are located at the outfall of a storm drainage structure, such as a culvert or storm drain. Concentrated flow at the structure outfall will plunge into one end of the pool forming a hydraulic jump at the other end against the apron. As a result, the flow will generally be well dispersed as it leaves the basin. This measure serves to prevent scour at the structure outlet, and to reduce flow velocities from the outlet, thus minimizing downstream erosion.

10.08.3.1.2 APPROPRIATE APPLICATIONS

This measure may be applied at a drainage structure outlet where the velocity at the design discharge is 15 feet per second or greater. It may also be used at structures with lower outlet flow velocities where the required length of a riprap apron would be excessive or infeasible due to site conditions.

10.08.3.1.3 LIMITATIONS

The use of this measure is not specifically limited; however, the designer should consider the available right-of-way area available, the availability of materials, and the difficulties which could be encountered when specifying this measure on a project.

Permanent riprap basin energy dissipators should not be used in streams or wetlands.

10.08.3.1.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is required as described below. For each riprap energy dissipator the dimensions listed in the "Riprap Basin Location, Dimensions, and Quantities" table on standard drawing EC-STR-21 should be labeled in the EPSC plans.

Riprap basin energy dissipators are described in Chapter 9 of this Manual. They may be designed using methods described in FHWA publication *HEC-14* with the modifications described in Section 9.04.2.

In contrast to temporary erosion prevention measures, which are usually designed using lower peak flow rate, a riprap energy dissipator should be considered a permanent structure and should be designed using the same flow rate used to design the drainage structure it is intended to serve. The basin dimensions may be modified as required to match the configuration of drainage structure end treatment.

This measure may be used as an alternative to a riprap apron where the required length of the apron would require additional right-of-way or permanent drainage easements.

Geotextile fabric (Type III) should be placed beneath the riprap used to construct a basin. Geotextile fabric (Type III) shall meet requirements of the standard specification for geotextiles AASHTO designation M-288, Erosion Control.

Permanent riprap basin energy dissipator shall be paid for under the following item numbers:

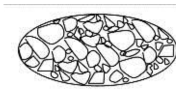
- 203-01, Road & Drainage Excavation (Unclassified), per CY
- 709-05.06, Machined Rip-Rap (Class A-1), per Ton
- 709-05.08, Machined Rip-Rap (Class B), per Ton
- 709-05.09, Machined Rip-Rap (Class C), per Ton
- 740-10.03, Geotextile (Type III) (Erosion Control), per SY

10.08.3.1.5 EXAMPLE APPLICATION

A detailed example of riprap basin energy dissipator design is provided in the Appendix to Chapter 9 of this Manual.

10.08.3.2 RIPRAP APRON OUTLET PROTECTION

Riprap Outlet Protection
Location: SR-72, Loudon County, TN (2004)



Riprap

10.08.3.2.1 DEFINITION AND PURPOSE

A riprap apron consists of a stone channel lining placed downstream from a storm drainage structure outlet. Riprap outlet protection is used to prevent outlet scouring, reduce water velocity, and distribute the energy from the flow leaving a pipe to prevent erosion in the downstream channel. In general, a riprap apron serves to line the downstream channel starting from the outlet of a drainage structure for a distance sufficient to diffuse the energy and velocity of the concentrated flow at the structure outfall.

10.08.3.2.2 APPROPRIATE APPLICATIONS

A riprap apron may be applied at the outlet of any storm drain, culvert, paved channel or slope drain. Although a riprap apron is usually a permanent structure, it may be applied at the outlet of temporary structures such as temporary diversion culverts. This measure should not be applied where the flow velocity at the drainage structure outlet exceeds 15 fps. In such cases, an energy dissipator should be considered, or the structure should be upsized.

10.08.3.2.3 LIMITATIONS

The required apron length is frequently quite long and may exceed the available project right-of-way. An energy dissipator may be used in place of an apron where site constraints make a long apron infeasible. This measure may not be suitable when the velocity of flow at the outfall equals or exceeds 15 feet per second.

10.08.3.2.4 PLANNING AND DESIGN CRITERIA

Where a riprap apron is used to serve a permanent drainage structure outfall, it should be designed using the same flow rate used to design the structure. Where aprons are proposed to accommodate a temporary structure, they may be designed using the 2-year peak flow rate. However, at sites which drain to Exceptional Tennessee Waters or sediment-impaired streams, temporary aprons should be designed to accommodate the 5-year, 24-hour peak flow rate. Chapter 6 provides detailed criteria for the design of a riprap apron at a pipe outfall.

Riprap aprons should be constructed on geotextile fabric which meets the requirements of the standard specification for geotextiles, AASHTO designation M-288, Erosion Control, Class A.

Riprap aprons shall be paid for under the following item numbers:

- 203-01, Road & Drainage Excavation (Unclassified), per CY
- 709-05.06, Machined Rip-Rap (Class A-1), per Ton
- 709-05.08, Machined Rip-Rap (Class B), per Ton
- 709-05.09, Machined Rip-Rap (Class C), per Ton
- 740-10.03, Geotextile (Type III) (Erosion Control), per SY

10.08.3.2.5 EXAMPLE APPLICATION

A detailed procedure for the design of riprap aprons is provided in Chapter 6 of this Manual. An example of these computations is provided in Section 10.08.1 of this Chapter. The following discussion provides an example of quantity computations for this measure.

Given: A design has been developed for a riprap apron for a 60-inch culvert which will have an outlet velocity of 9.76 fps at the design discharge. The channel downstream of the culvert is trapezoidal in shape with a 6-foot wide bottom and 2H:1V side slopes which are 4 feet high. The design computations show that the apron should be 51 feet long.

Find: Compute the required quantities for this apron.

Solution: Since the outlet velocity from the culvert at the design discharge is between 5 and 10 fps, machined riprap (Class B) will be used to construct the apron. As provided in the TDOT Standard Specifications, the thickness of the riprap layer will be 2.5 feet.

<u>Item Number 203-01, Road and Drainage Excavation (Unclassified), per CY</u>

Since the riprap is to be placed so that the outer face of the layer is at the finished grade of the channel, it will be necessary to excavate an additional 2.5 feet of depth, as shown in Figure 10FC-1. To compute the quantity of excavation, the cross sectional area of the space required for the riprap will be computed and then multiplied by the length of the apron.

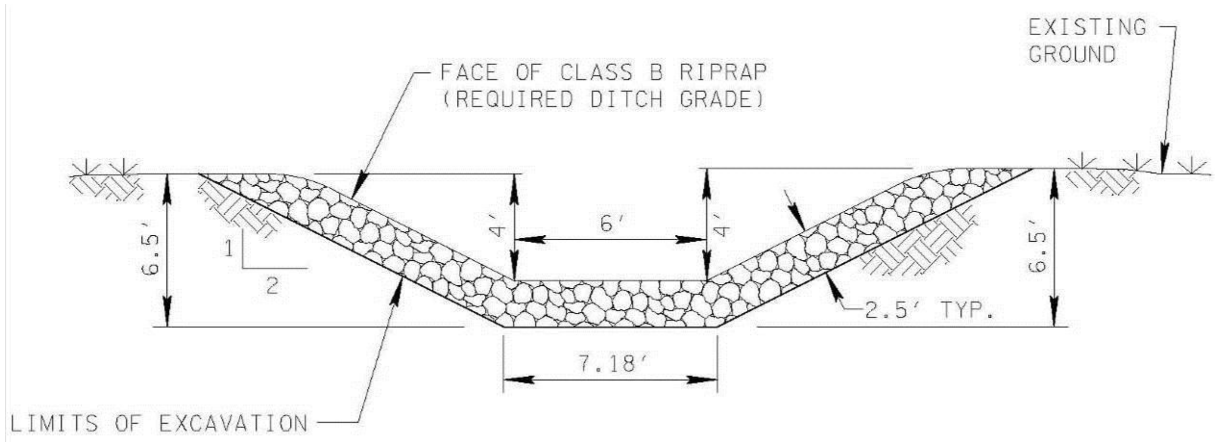


Figure 10FC-1
Cross Section of Riprap Apron

To compute the cross sectional area, the length of the perimeter along the inside of the layer (equivalent to the channel surface) will be computed as well as the perimeter along the outside of the riprap layer (equivalent to the bottom of the excavation). Since the channel is 4 feet deep, the length of one side of the inside perimeter may be computed as:

$$Length_{side} = \sqrt{Depth^2 + (2 \times Depth)^2} = \sqrt{4^2 + (2 \times 4)^2} = 8.94 \text{ feet}$$

The inside perimeter may be then be computed as:

$$P_{inside} = 8.94 + 6 + 8.94 = 23.89 \text{ feet}$$

As shown in Figure 10FC-1, the bottom width of the outside perimeter will be equal to 7.18 feet, and the height of the sides will be 6.5 feet. Thus, the length of one side is computed as:

$$Length_{side} = \sqrt{Depth^2 + (2 \times Depth)^2} = \sqrt{6.5^2 + (2 \times 6.5)^2} = 14.53 \text{ feet}$$

The perimeter along the outside of the excavation may then be computed as:

$$P_{outside} = 14.53 + 7.18 + 14.53 = 36.24 \text{ feet}$$

The average of these two perimeter lengths may then be multiplied by the layer thickness to determine the cross sectional area of the excavation:

$$Area = \left(\frac{23.89 + 36.24}{2}\right)2.5 = 75.16 \text{ SF}$$

This, in turn, is multiplied by the length of the apron to compute the final quantity:

$$Volume = 75.16 \times 51 = 141.96 \approx 142 \text{ CY}$$

<u>Item number 740-10.03, Geotextile (Type III) (Erosion Control), per SY</u>

The required area of geotextile should be computed based on the perimeter along the outside of the excavated area. Thus, the final quantity may be computed as:

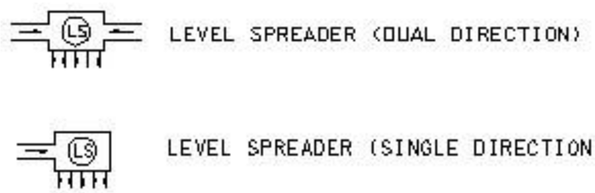
$$Area = 36.24 \times 51 = 1849 SF \times \frac{1\ SY}{9\ SF} = 206 \text{ SY}$$

<u>Item number 709-05.06, Machined Rip-Rap (Class B), per Ton:</u>

The required volume of riprap will be equal to the volume of excavation, computed as 142 CY. Thus, the final quantity of riprap may be converted to tons as specified in Section 10.04.6.

$$142\,\text{CY} \times \frac{1.75\ Tons}{1\ CY} = 248.5 \approx 249 \text{ Tons}$$

10.08.3.3 LEVEL SPREADER (EC-STR-61)



Constructed Level Spreader (Type 3)
Source: BEA Group at NC State University

10.08.3.3.1 DEFINITION AND PURPOSE

A level spreader is a flow control measure that receives concentrated, potentially erosive inflows and converts them to a sheet flow condition by means of a horizontal weir and channel. Its purpose is to spread concentrated stormwater runoff over a wide enough area that erosion will be prevented on the receiving area downslope of the measure. Although the stormwater released from a level spreader will be in a sheet flow condition, a good cover of vegetation is essential downstream of the weir to ensure the effectiveness of the measure. As a secondary benefit, a level spreader may remove other pollutants present in the stormwater runoff by means of infiltration, absorption, evaporation, etc.

10.08.3.3.2 APPROPRIATE APPLICATIONS

A level spreader may be used at any location where:

- the existing ground slopes away from the project
- the downstream slope from the structure is uniform, free of irregularities, and sloped at 10% or less
- where the existing vegetation consists of either dense turf grasses or wooded areas with undergrowth and forest litter
- where project derived concentrated flows will discharge into required buffer zones
- where a completed project will produce a concentrated stormwater discharge point onto an adjacent property which previously received sheet flow at the same location

Level spreaders should release flows onto areas which will not be disturbed by the proposed project.

A level spreader may be useful on a permanent basis to restore a sheet flow condition where an installed cross drain or other structure will result in the concentration of previously present sheet flows from the upstream side of the roadway. As a temporary measure, a level spreader may be used as an outlet for a system of temporary diversion berms, provided that appropriate erosion prevention and sediment control measures are utilized upslope of the level spreader. In any case, a level spreader may eliminate or prevent the need for disturbance necessary to construct an outlet ditch from a project outfall to the receiving stream. This is especially important in areas where a riparian buffer zone is to be preserved along a stream. In addition, allowing the sheet flow to pass through vegetated areas may provide an additional filtration function.

10.08.3.3.3 LIMITATIONS

The weir in a level spreader must be level for the measure to function properly. Variations in the weir profile may cause flows to re-concentrate, potentially causing failure of the structure and/or erosion on the slope downgrade of the level spreader. Level spreaders should not be located where the weir will be at or above the finish grade of the adjacent subgrade.

Even when a level spreader is functioning as intended, the sheet flow it releases will tend to re-concentrate at some point below the device. Thus, the measure should be placed no more than 300 feet from a stable stream, ditch, or swale capable of conveying the discharge from the level spreader. The slope S_d downstream of the level spreader should be 10% or less.

A level spreader is not a sediment control device. During construction, areas draining to the structure should be provided with appropriate erosion prevention and sediment control measures in order to prevent the buildup of sediment in the level spreader channel. Because of this, a level spreader may require a high degree of maintenance, including inspection, mowing, and cleanout of accumulated material, even after the project has been stabilized.

Level spreaders should not be constructed where access for inspection and maintenance is impractical or impossible. Additionally, due to pool depth and drawdown time of the channel, consideration should be given to forgoing installation of this measure where it will be easily accessible to children such as along a pedestrian school route.

10.08.3.3.4 PLANNING AND DESIGN CRITERIA

Formal design of this measure is not required. However, the length (L) and depth (D) for each level spreader should be listed in the EPSC plans. The required dimensions may be determined from the tables provided on EC-STR-61.

The ground slope downstream of the structure should be no more than 10%. As shown on the Standard Drawing, the required weir length may become quite large where the downstream slope is greater than 4%. The weir should be placed on otherwise undisturbed ground and the slope downstream of the structure should either be undisturbed during the project construction or should already be permanently stable with a good stand of vegetation.

In general, level spreaders for temporary use should be designed based on the storm frequencies specified in Section 10.05.1.3. At locations that drain to Exceptional Tennessee Waters or sediment-impaired streams, temporary level spreaders should be designed for the 5-year storm event. Level spreaders for permanent use should be designed using the 10-year storm event. Level spreaders may accept concentrated inflows from one or both ends of the device. When flow enters from only one end, the opposite end of the structure shall be provided with a compacted berm to prevent overflows. This berm shall be a minimum of 9 inches.

Both the channel and the weir are necessary parts of the function of a level spreader. The channel should be sufficiently deep to ensure that inflows will spread evenly across the length of the structure. In addition, the low point of the channel cross section is set back from the weir to minimize the potential for longitudinal currents in the outflow.

A transition should be provided between the berm or ditch cross section bringing flows into a level spreader and the level spreader channel cross section. The length of this transition should be at least 2 times the depth of the level spreader channel as shown on the standard drawing. In addition, the transition should be completed at least 2 feet upstream of the start of the overflow weir.

The channel and weir must be level in order for flows in the level spreader to be uniformly spread out. Thus, the level spreader should be installed along the contour of the slope and the maximum deviation from horizontal for the overflow weir should be no more than 1/8th of an inch per 10 lineal feet of weir. If necessary, the structure may be installed on a non-linear horizontal alignment to meet these criteria.

Ideally, the ground surface on the downstream side of the weir should be flush with the weir crest. Where variations in the ground surface result in areas being below the top of the weir; the ground may be “leveled” by placing size 57 aggregate on geotextile fabric (Type III). The top of the aggregate should be level with the top of the weir. Where possible, the aggregate should be placed at a 4H:1V slope or flatter.

Type 1 weirs for level spreaders may be constructed from soil protected by erosion control blanket, provided that the soil can be graded level. Usually, this will be limited to weir lengths of 10 feet or less and should be considered for temporary use only. Longer weirs (up to a practical maximum of 200 feet) for temporary level spreaders may be constructed using 6 x 6 pressure-treated timbers, to form a Type 2 weir. Type 3 weirs for permanent installations should be constructed of cast-in-place concrete.

Level spreaders with Type 1 and Type 2 weirs should be considered to have a service life of approximately 1 year. If a temporary level spreader is to be used for a longer period, it may be necessary to reconstruct or re-level the weir. Level spreaders for permanent applications are generally considered to have a life span of 10 to 20 years.

The presence of a permanent level spreader on or near the toe of an embankment may pose a hazard to Maintenance Division mowing crews. Appropriate use of delineator posts is recommended to mark the extents of the measure. Mowing equipment (except in the case of string trimmers) operating on the weir will likely damage the structure. Additionally, damage by mowing equipment to the receiving area down slope of the weir will reduce the effectiveness and functionality of this BMP.

Level spreaders should be shown on the EPSC plan using the appropriate symbol, with notes indicating the type and length of the weir as well as depth of the channel.

Level Spreaders shall be paid for under the following item number:

- 805-01.69, Level Spreaders, per Each

10.08.3.3.5 EXAMPLE APPLICATION

Given: A vertical curve correction is proposed for a highway in Overton County. This project will require that additional fill be placed on the existing 4H:1V roadway embankment. The completed embankment will have an average height of 12 feet and will be 700 feet long.

In the existing condition, this portion of the roadway does not have a side ditch. Rather, water drains from the project in a sheet flow condition and flows approximately 250 feet overland to a nearby stream. This stream has been identified by TDEC as Exceptional Tennessee Waters due to its recreation value and an abundance of aquatic life. It also has a forested riparian band of approximately 100 feet, which must be preserved. From the toe of the embankment to the creek, the ground has a slope of about 1%.

During construction, a system of temporary diversion berms will be utilized to minimize erosion on the embankment. These berms will intercept sheet flow on the embankment and redirect it to a riprap lined swale. Due to the site conditions, it is desired to use a level spreader to return flows from the riprap swale to a sheet flow condition.

Find: Determine the required dimensions for a level spreader at this site.

Solution:

Step 1: Determine the level spreader location: Inspection of the project plans indicates that the point of closest approach between the toe of the embankment and the stream is at about the midpoint of the embankment. Since this is also the point of lowest elevation at the interface between the proposed embankment and the existing ground, it is decided to place the level spreader at this location and allow flow to enter from both ends.

Step 2: Determine the design discharge for the level spreader: Since the receiving stream is listed as an Exceptional Tennessee Waters, it will be necessary to design the level spreader for the 5-year/24-hour storm. Based on an analysis of flow times on the slope, it appears that the time of concentration for flows into the level spreader will be 5 minutes. Thus, the 5-minute rainfall intensity will be used in the Rational Method computations to determine the design discharge. From Chapter 4 of this Manual, it is observed that Overton County is located in the Cookeville IDF Zone. Thus, the Cookeville curves are used to determine a 5-year, 5-minute rainfall intensity of approximately 6.4 inches per hour.

Since the embankment will be at a 4H:1V slope and have an average height of 12 feet, the average slope length, L_s, may be computed as:

$$L_s = \sqrt{12^2 + (4 \times 12)^2} = 49.5 \text{ feet}$$

The drainage area, A, may in turn be computed as:

$$A = \frac{49.5 \times 700}{43{,}560} = 0.795 \text{ acres}$$

Given a Rational Coefficient of 0.94, the design discharge for the structure may be computed as:

$$Q = CiA = 0.94(6.4)(0.795) = 4.8 \text{ cfs}$$

Step 3: Determine the level spreader dimensions and select the weir type: Based on the table "Unit Weir Flow Rates" on the standard drawing, a unit discharge of 0.49 cfs/LF is required for the given downstream slope of 1%. Thus, the weir length, L, may be computed as:

$$L = \frac{4.8\ cfs}{0.49\ cfs/LF} = 9.8 \text{ LF (round to 10 LF)}$$

Interpolating from the table "Minimum Level Spreader Channel Depth" on the standard drawing yields a required depth of about 1.6 feet. Since this level spreader will be a temporary structure with a weir length of about 10 feet, it would be possible to construct the weir out of earth protected by erosion control blanket. However, given the fact that the receiving waters are environmentally sensitive, it is decided to use a Type 2 weir so that it can be constructed from a single 6 x 6 x 10-foot treated timber. This will allow for a more uniform weir profile as well as greater control of the horizontal grade.

Although the weir will be 10 feet long, the total channel length should include 2 additional feet on either end of the weir, plus two transitions. Since the transition length is 2 times the depth of the channel, each transition should be 3.2 feet. Thus, the total length of the channel, with the transitions, will be 20.4 feet. This result is rounded up to 21 feet by stretching both transitions to 3.5 feet in length.

10.08.3.4 PERMANENT DETENTION / RETENTION BASIN

[No EPSC Plan Symbol – See notes below]

Permanent Detention Basin w/ Low-Flow Concrete Trickle Ditch for Drainage
Location: US-41, Nashville, TN (2006)

10.08.3.4.1 DEFINITION AND PURPOSE

Detention/retention basins serve to capture stormwater runoff from a roadway or other developed area and release it at a rate that is equal to or less than the pre-developed runoff rate. In some applications, these structures may also be used to remove sediment from the site runoff. These BMPs reduce the potential for downstream erosion caused by increased runoff rates from the development. They also prevent sedimentation in the receiving stream by intercepting potentially sediment laden stormwater from the developing site.

10.08.3.4.2 APPROPRIATE APPLICATIONS

The three principal types of basin are the detention basin, the extended detention basin, and the retention basin. All three types of structure may be used to control developed conditions flow rates. Retention and extended detention basins are used to remove sediments from runoff by allowing sediment laden water to stand for an extended period of time. Since retention basins include a permanent pool which has no outlet, it provides the greatest potential for sediment removal. The conditions in which detention, extended detention, and retention basins apply are described in Chapter 8 of this Manual.

10.08.3.4.3 LIMITATIONS

Although detention basins may provide effective water quantity control, they often are not effective for water quality control. Further, extended detention and retention basins will usually hold ponded water for longer periods of time, and may pose a hazard if located to close to the roadway. All three types of basin may require additional right-of-way, with retention basins typically requiring the most. Additionally, these facilities require inspection and maintenance throughout their entire service lives.

10.08.3.4.4 PLANNING AND DESIGN CRITERIA

These basins consist of a surface reservoir, outflow device, and emergency overflow structure. Chapter 8 contains detailed information on the planning and design of detention and retention basins.

Extended detention and retention basins are usually designed to capture the "first flush" runoff from a developed area. Information on the design of these basins may be found in Section 8.04 of this Manual. Design procedures may be found in Section 8.05. Because they are permanent structures, the outline of the proposed basin should be shown on the EPSC plan sheet with the appropriate labels.

Figure 10FC-2
Permanent Detention Basin under Construction
Location: SR-37, Carter County, TN (2005)

Maintenance considerations for these basins include many issues in addition to the removal of accumulated sediments. Section 8.06 provides a thorough discussion of the maintenance issues to be considered during the design of these basins.

10.08.3.4.5 EXAMPLE APPLICATION

The design of a detention/retention basin can be a complicated process. Thus, a design example for this BMP is not provided within this chapter. A design example for an extended detention outlet structure is provided in Chapter 8 of this Manual. Chapter 8 also provides examples for the design of facilities for quantity control. The designer should refer to Chapter 8 and other referenced documents for the proper analysis and design of these measures. The designer should have an understanding of hydrology, hydraulics, and storm routing.

TDOT DESIGN DIVISION

DRAINAGE MANUAL

CHAPTER X
APPENDIX 10A

SECTION 10.09 – APPENDIX

10.09.1 FIGURES AND TABLES

10.09.1.1 FIGURES AND TABLES

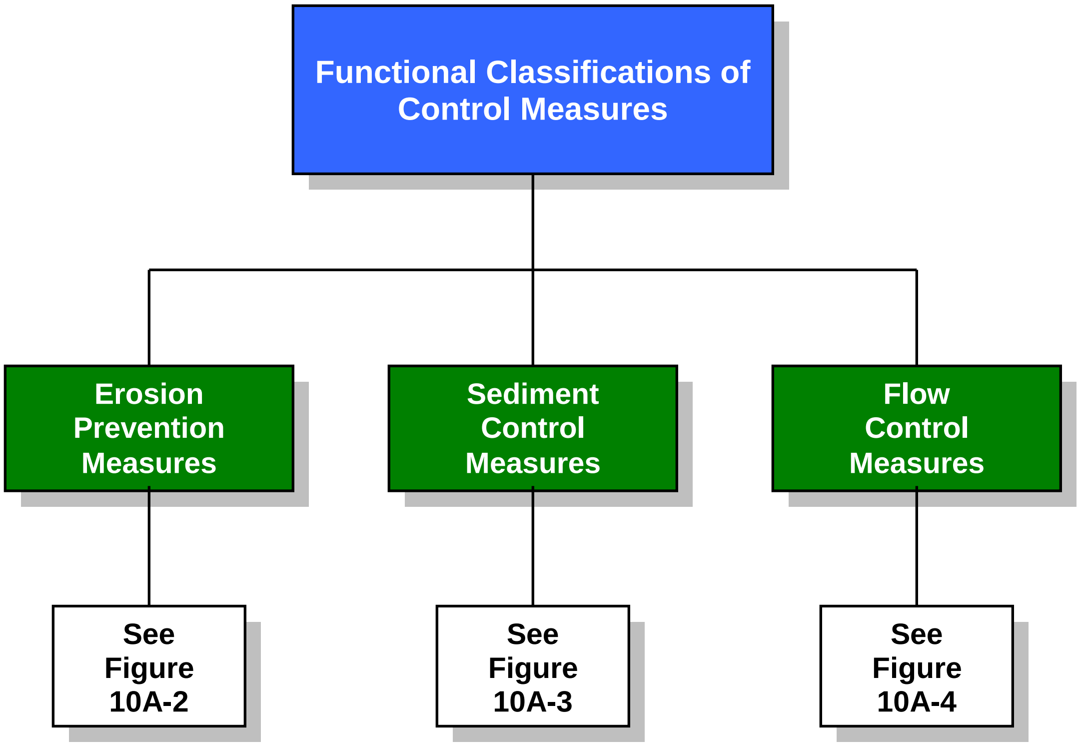
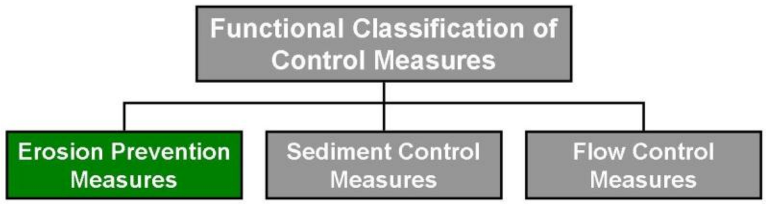


Figure 10A-1
Functional Classification of Control Measures Flow Chart

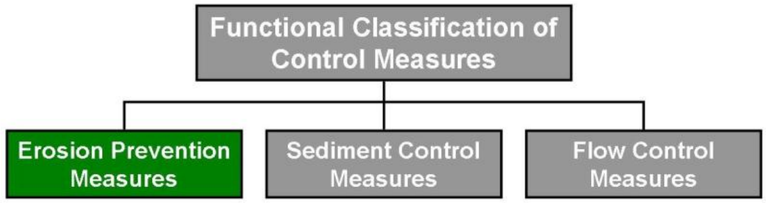
EROSION PREVENTION MEASURES (Page 1 of 4)



BMP NAME	DESCRIPTION AND USES	Where: Road Cuts / Fills	Where: Graded Areas	Where: Ditches / Swales	Life: Temporary	Life: Permanent	Type: Vegetative	Type: Structural	Type: Other
Enhanced Silt Fence Check	▪ Used for reducing velocity of flow in channels ▪ Performs by both settlement and by filtration ▪ Trapezoidal or V-ditches ▪ Section 10.08.1.1 & EC-STR-3D, 4, 4A			●	●			●	
Rock Check Dam	▪ Used for reducing velocity of flow in channels ▪ Little, if any, sediment trapping capabilities ▪ Maximum drainage area is 10 acres ▪ Section 10.08.1.2 & EC-STR-6			●	●			●	
Temporary Construction Exit	▪ Uses a rock pad to remove mud from vehicle tires to minimize vehicle tracking of sediment ▪ Required at ingress / egress points to public roads and streets ▪ Section 10.08.1.3 & EC-STR-25		●		●			●	
Temporary Culvert Crossing	▪ Uses one or more pipes with riprap to allow construction vehicles across a stream ▪ Prevents erosion damage to channel banks ▪ Should be in-place one year or less ▪ Section 10.08.1.4 & EC-STR-25			●	●			●	
Temporary Construction Ford	▪ Uses riprap on the bottom of certain ditches and swales to allow construction access ▪ Prevents erosion damage to channel banks ▪ In place one year or less ▪ Section 10.08.1.5 & EC-STR-25			●	●			●	
Temporary Slope Drain	▪ Uses a pipe to convey flows down a slope to the bottom minimizing erosion potential ▪ Prevents flows from eroding cut or fill slopes ▪ Maximum drainage area is 1.5 acres ▪ Section 10.08.1.6 & EC-STR-27	●			●			●	
Temporary Berm	▪ Uses a compacted earthen mound to divert flows around an erodible area ▪ Useable life is typically 18 months ▪ Maximum drainage area is 5 acres ▪ Section 10.08.1.7 & EC-STR-27	●	●		●			●	

Figure 10A-2 (1 of 4)
Erosion Prevention BMPs

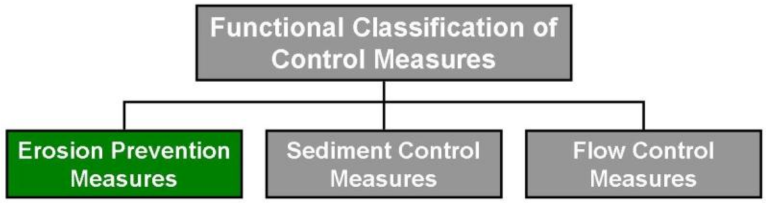
EROSION PREVENTION MEASURES (Page 2 of 4)



BMP NAME	DESCRIPTION AND USES	Where: Road Cuts / Fills	Where: Graded Areas	Where: Ditches / Swales	Life: Temporary	Life: Permanent	Type: Vegetative	Type: Structural	Type: Other
Temporary Diversion Channel	▪ Conveys stream flow around a project area ▪ Open channel using riprap and geotextile to divert flow away from immediate work zone ▪ Maximum drainage area is 1280 acres ▪ Section 10.08.1.8 & EC-STR-31 & 31A			●	●			●	
Temporary Diversion Culvert	▪ Conveys stream flow around a project area ▪ Uses temporary pipe to divert flow away from immediate erodible work zone ▪ Maximum drainage area is 1280 acres ▪ Section 10.08.1.9 & EC-STR-32			●	●			●	
Suspended Pipe Diversion	▪ Allows the extension of a box culvert, etc… ▪ Uses pipe suspended above culvert floor ▪ Maximum drainage area is 1280 acres ▪ Section 10.08.1.10 & EC-STR-33 & 33A			●	●			●	
Erosion Control Blanket	▪ Organic fibers with degradable synthetic or natural netting. ▪ Provides erosion protection for seed and fertilizer while vegetation establishes ▪ Section 10.08.1.11 & EC-STR-34	●	●	●	●		●		
Turf Reinforcement Mat	▪ Uses organic fibers combined with a non degradable netting to reinforce turf ▪ Non degradable netting with mature grass provides highly erosion-resistant channel lining ▪ Section 10.08.1.12 & EC-STR-36	●	●	●	●	●	●	●	
Gabion Check Dam	▪ Used for reducing velocity of flow in channels ▪ Very minor sediment trapping capabilities ▪ More expensive and labor-intensive than rock check dams but greater in mass ▪ Section 10.08.1.13 & EC-STR-55 through 59			●	●	●		●	
Slope Surface Roughening	▪ Typically used on slopes 3H:1V and steeper ▪ Reduces erosion by slowing flow velocities ▪ Increases infiltration & sediment trapping ▪ Aids in the establishment of vegetative cover ▪ Section 10.08.1.14	●	●		●				●

Figure 10A-2 (2 of 4)
Erosion Prevention BMPs

EROSION PREVENTION MEASURES (Page 3 of 4)



BMP NAME	DESCRIPTION AND USES	Where: Road Cuts / Fills	Where: Graded Areas	Where: Ditches / Swales	Life: Temporary	Life: Permanent	Type: Vegetative	Type: Structural	Type: Other
Seeding and Mulch	▪ Reduces erosion by stabilizing exposed soils ▪ Mulch provides immediate temporary protection from raindrop erosion ▪ Mulch enhances growth by retaining moisture ▪ Section 10.08.1.15	●	●	●	●	●	●		
Construction Phasing	▪ Limits exposed areas by clearing vegetation and rough grading one section at a time ▪ Phasing plan usually developed by Contractor ▪ Phases should correlate with site activities ▪ Section 10.08.1.16	●	●	●	●				●
Manage Slope and Ditch Grades	▪ Limit length and grade of slopes, where feasible, to reduce erosion potential ▪ Reduces erosion potential by avoiding abrupt breaks in grade and steep slopes in ditches ▪ Section 10.04.5	●	●	●		●			●
Bench Terraces and Stair Step Grading	▪ Reduces erosion by breaking up long or steep slopes preventing concentrated flow ▪ May channel runoff to stable outfall location ▪ Aides with germination of slope vegetation ▪ Section 10.04.5	●			●	●			●
Horizontal and Vertical Rounding	▪ Vertical rounding shown in TDOT Standard Drawings; horizontal shown on grading plan ▪ Eliminates sharp breaks in grade where erosion can begin. Minimizes erosion chance ▪ Section 10.04.5	●	●	●		●			●
Water for Dust Control	▪ Part of normal “housekeeping” operations ▪ Prevents wind erosion and reduces fugitive dust ▪ Section 10.04.4.3	●	●		●				●
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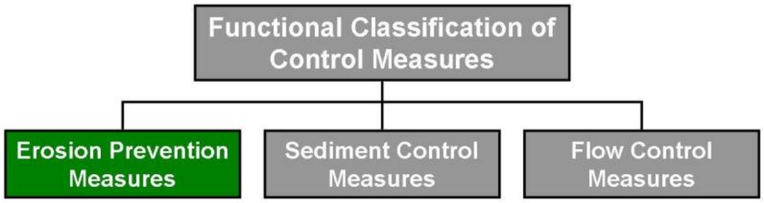
Figure 10A-2 (3 of 4)
Erosion Prevention BMPs

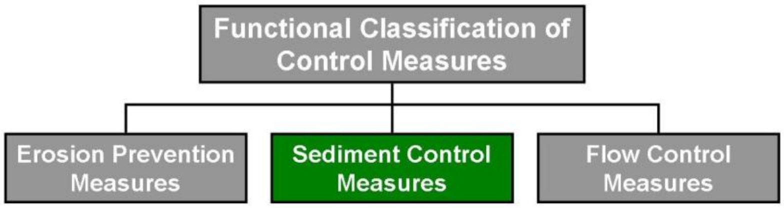
EROSION PREVENTION MEASURES (Page 4 of 4)



BMP NAME	DESCRIPTION AND USES	Where			Life		Type		
		Road Cuts / Fills	Graded Areas	Ditches / Swales	Temporary	Permanent	Vegetative	Structural	Other
	(The following lines reserved for future use)								

Figure 10A-2 (4 of 4)
Erosion Prevention BMPs

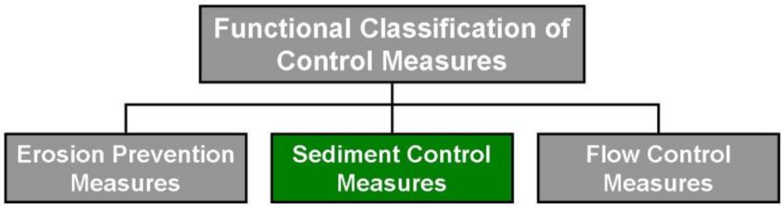
SEDIMENT CONTROL MEASURES (Page 1 of 3)



BMP NAME	DESCRIPTION AND USES	Where: Road Cuts / Fills	Where: Graded Areas	Where: Ditches / Swales	Life: Temporary	Life: Permanent	Type: Vegetative	Type: Structural	Type: Other
Dewatering Structure	▪ Temporarily holds runoff to allow sediments to drop out; can also filter sediments ▪ Most often used for pumped effluent from dewatering operations at watercourse ▪ Section 10.08.2.1 & EC-STR-1				●			●	
Sediment Filter Bag	▪ Sediment trapping device used for pumped effluent from dewatering operations ▪ Geotextile bag retains large sediments while allowing filtered water to pass through ▪ Section 10.08.2.2 & EC-STR-2				●			●	
Silt Fence	▪ Sheet flow only. Installed on contour ▪ Woven geotextile fabric on wood or metal posts, trenched into the ground. ▪ Max ¼th acre of area per 100 LF of fence ▪ Ponds water to allow sediments to settle out ▪ Section 10.08.2.3 & EC-STR-3B & 3E	●	●		●			●	
Silt Fence with Wire Backing	▪ Sheet flow only. Installed on contour ▪ Includes a woven wire fence backing ▪ Used adjacent to a water course or body ▪ Ponds water to allow sediments to settle out ▪ Section 10.08.2.4 & EC-STR-3C & 3E	●	●		●			●	
Enhanced Silt Fence	▪ Reduces velocity to allow sediment to settle out; also provides some filtration capacity ▪ Used to form check dams in ditches/swales ▪ Designed to withstand forces of flowing water ▪ Section 10.08.2.5 & EC-STR-3D, & 3E			●	●			●	
Enhanced Rock Check Dam	▪ Traps and filters sediments in a ditch / swale ▪ Uses a riprap check dam with a layer of #57 stone, with geotextile between stone layers ▪ Maximum drainage area is 30 acres ▪ Section 10.08.2.6 & EC-STR-6A			●	●			●	
Sediment Trap with Check Dam	▪ Captures and filters sediment from flow ▪ Not used in or other natural water resources streams ▪ Maximum drainage area is 3 acres ▪ Section 10.08.2.7 & EC-STR-7			●	●			●	

Figure 10A-3 (1 of 3)
Sediment Control BMPs

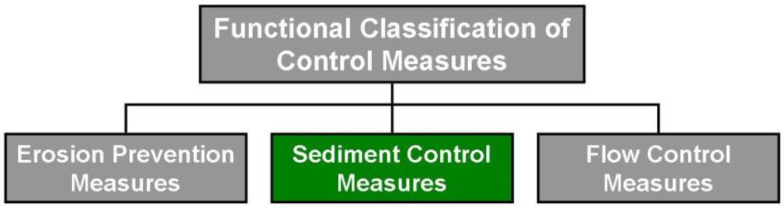
SEDIMENT CONTROL MEASURES (Page 2 of 3)



BMP NAME	DESCRIPTION AND USES	Where: Road Cuts / Fills	Where: Graded Areas	Where: Ditches / Swales	Life: Temporary	Life: Permanent	Type: Vegetative	Type: Structural	Type: Other
Filter Sock	▪ Slows flow of runoff so that sediments can settle out, can also filter runoff ▪ Long sock with mulch and/or wood chips ▪ For use on slopes or in ditches ▪ Section 10.08.2.8 & EC-STR-8	●	●	●	●			●	
Culvert Inlet Protection Type 1 and Type 2	▪ Traps and filters sediments at a culvert inlet ▪ Uses a #57 stone or other measures to surround the culvert inlet ▪ Type 2 allows run-on flows to pass through ▪ Section 10.08.2.9 & EC-STR-11 & 11A	●			●			●	
Rock Sediment Dam	▪ Traps and filters sediments in a ditch / swale ▪ Composed of a riprap structure with a layer of #57 stone, with geotextile in between ▪ Used for drainage areas > 30 acres ▪ Section 10.08.2.10 & EC-STR-12			●	●			●	
Rock and Earth Sediment Embankment	▪ Reduces flow velocities in a stream to allow sediments to settle out ▪ Retains entire design storm runoff volume ▪ Section 10.08.2.11 & EC-STR-13		●	●	●			●	
Sediment Basin	▪ Holds runoff to allow sediments to drop out ▪ Excavated reservoir with outlet works, including a floating outlet structure (surface drawdown device) ▪ Drainage area between 10 and 50 acres ▪ Section 10.08.2.12 & EC-STR-15, 16 & 17	●	●		●	●		●	
Catch Basin Protection	▪ Slows flow of runoff into a catch basin so that sediments can settle out, can also filter runoff ▪ Can use riprap, #57 stone, geotextile, or sediment tube ▪ Section 10.08.2.13 & EC-STR-19		●	●	●			●	
Filter Berm	▪ Slows flow of runoff on a slope so that sediments can settle out, can also filter runoff ▪ Can be composed of wood chip mulch or a mix of wood chips and compost ▪ Section 10.08.2.14 & EC-STR-35	●	●		●			●	

Figure 10A-3 (2 of 3)
Sediment Control BMPs

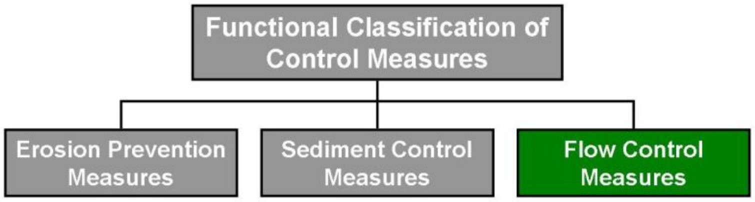
SEDIMENT CONTROL MEASURES (Page 3 of 3)



BMP NAME	DESCRIPTION AND USES	Where: Road Cuts / Fills	Where: Graded Areas	Where: Ditches / Swales	Life: Temporary	Life: Permanent	Type: Vegetative	Type: Structural	Type: Other
Sediment Tube	▪ Slows flow of runoff so that sediments can settle out, can also filter runoff ▪ Composed of flexible tube with fibrous filler ▪ Slopes or ditches ▪ Section 10.08.2.15 & EC-STR-37	●	●	●	●			●	
Floating Turbidity Curtain	▪ Floating geotextile barrier in a lake or river ▪ Contains sediments generated either on-shore or in the water ▪ Section 10.08.2.16 & EC-STR-38				●			●	
Curb Inlet Protection	▪ Four types which either slow flow of runoff so that sediments can settle out, or filter runoff ▪ Used at curb inlets during construction ▪ Can create significant ponding ▪ Section 10.08.2.17 & EC-STR-39 & 39A				●			●	
Catch Basin Filter Assemblies	▪ Traps and filters sediments prior to entering a catch basin ▪ Consists of entrenched geotextile fabric on a frame above the catch basin ▪ Section 10.08.2.18 & EC-STR-40 thru 51A			●	●			●	
	(The following lines reserved for future use)								

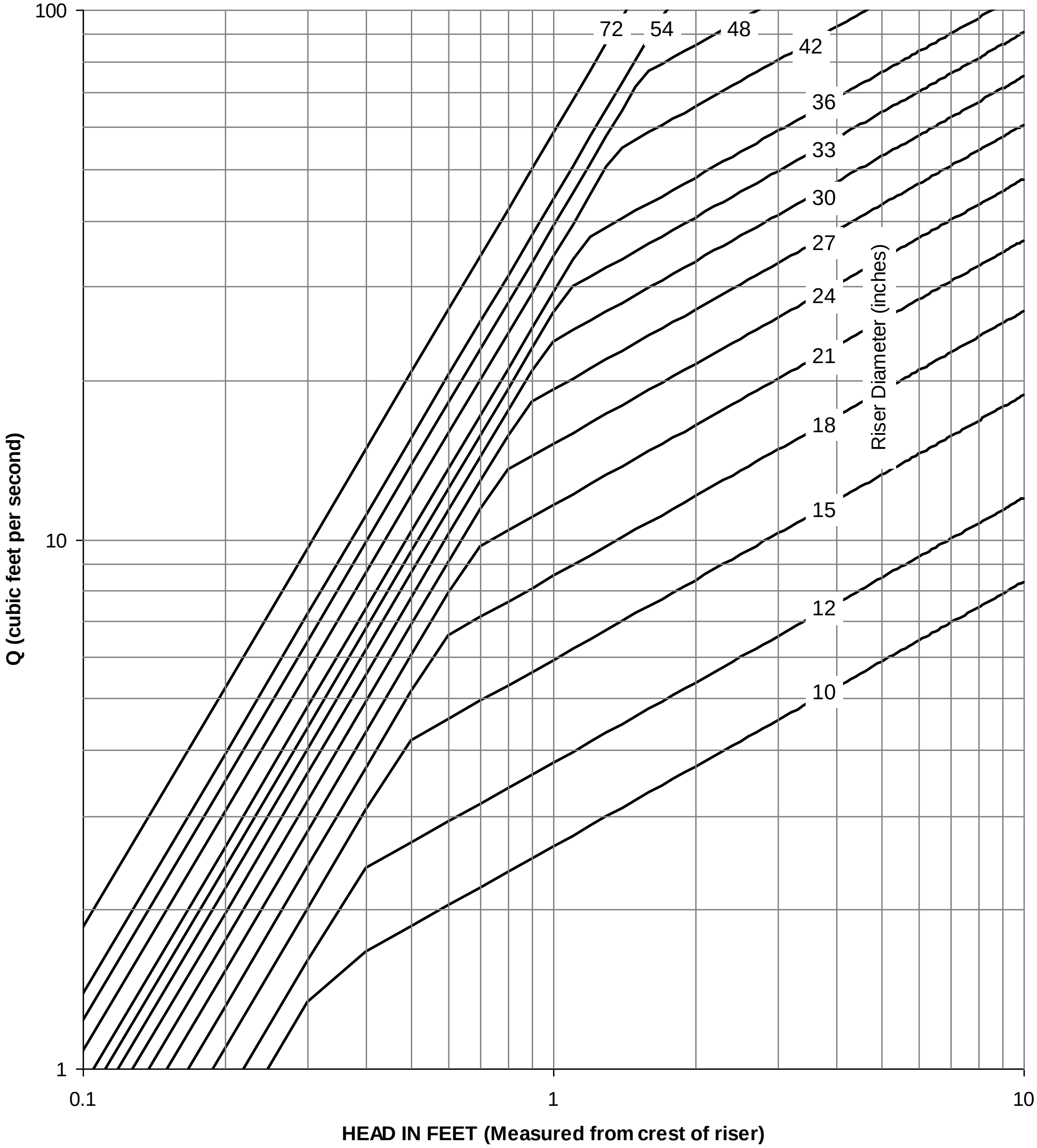
Figure 10A-3 (3 of 3)
Sediment Control BMPs

FLOW CONTROL MEASURES



BMP NAME	DESCRIPTION AND USES	Where: Road Cuts / Fills	Graded Areas	Ditches / Swales	Life: Temporary	Permanent	Type: Vegetative	Structural	Other
Permanent Riprap Energy Dissipator	▪ Riprap basin at a high-velocity outlet point ▪ Used at culverts, ditch outfalls, etc. ▪ For outlet velocities greater than 15 fps ▪ Sections 10.08.3.1; 6.04.3.3 & EC-STR-21			●	●	●		●	
Riprap Apron Outlet Protection	▪ Riprap structure to prevent erosion at outfalls ▪ Used primarily for culverts ▪ Where apron length is excessive, may substitute a riprap energy dissipator ▪ Sections 10.08.3.2; 6.05.5			●		●		●	
Level Spreader	▪ Collects concentrated flow and converts it back to a sheet flow condition ▪ Prevents erosion on the downstream slope ▪ Utilizes level pool and horizontal weir ▪ Section 10.08.3.3 & EC-STR-61	●	●		●	●		●	
Permanent Detention / Retention Basin	▪ Prevents erosion in streams down from a project by limiting post-project flow rates ▪ Usually very little sediment removal ▪ Sections 10.08.3.4; 8.04,.4; 8.04.9; 8.05.8			●		●		●	
	(The following lines reserved for future use)								

Figure 10A-4
Flow Control BMPs



$$Q_{weir} = 9.739\ D\ H^{3/2}$$
$$Q_{orifice} = 3.782\ D^2\ H^{1/2}$$

Slope change occurs at weir – orifice transition.

Figure 10A-5
Riser Inflow Curves
Reference: SWMM for Western Washington (2005)

County	R-Factor	County	R-Factor	County	R-Factor
Anderson	180	Hamilton	250	Morgan	190
Bedford	240	Hancock	160	Obion	260
Benton	245	Hardeman	285	Overton	200
Bledsoe	220	Hardin	280	Perry	260
Blount	190	Hawkins	150	Pickett	190
Bradley	250	Haywood	275	Polk	250
Campbell	175	Henderson	260	Putnam	210
Cannon	220	Henry	240	Rhea	215
Carroll	255	Hickman	240	Roane	190
Carter	160	Houston	235	Robertson	220
Cheatham	225	Humphreys	240	Rutherford	225
Chester	275	Jackson	210	Scott	180
Claiborne	165	Jefferson	170	Sequatchie	235
Clay	200	Johnson	150	Sevier	185
Cocke	170	Knox	180	Shelby	290
Coffee	235	Lake	260	Smith	215
Crockett	270	Lauderdale	275	Stewart	235
Cumberland	200	Lawrence	265	Sullivan	150
Davidson	225	Lewis	255	Sumner	215
Decatur	260	Lincoln	260	Tipton	280
DeKalb	215	Loudon	190	Trousdale	215
Dickson	235	McMinn	220	Unicoi	165
Dyer	270	McNairy	285	Union	170
Fayette	285	Macon	210	Van Buren	215
Fentress	190	Madison	270	Warren	220
Franklin	255	Marion	250	Washington	160
Gibson	265	Marshall	240	Wayne	270
Giles	260	Maury	240	Weakley	255
Grainger	165	Meigs	215	White	210
Greene	160	Monroe	215	Williamson	235
Grundy	235	Montgomery	230	Wilson	220
Hamblen	165	Moore	250		

Table 10A-1
RUSLE Equation R-Values for Tennessee Counties
Reference: USDA, NRCS-TN (2001)

Slope (%)	Slope Length (feet)																
	<3	6	9	12	15	25	50	75	100	150	200	250	300	400	600	800	1000
0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
0.5	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.09	0.09	0.10	0.10	0.10	0.11	0.12	0.12	0.13
1.0	0.09	0.09	0.09	0.09	0.09	0.10	0.13	0.14	0.15	0.17	0.18	0.19	0.20	0.22	0.24	0.26	0.27
2.0	0.13	0.13	0.13	0.13	0.13	0.16	0.21	0.25	0.28	0.33	0.37	0.40	0.43	0.48	0.56	0.63	0.69
3.0	0.17	0.17	0.17	0.17	0.17	0.21	0.30	0.36	0.41	0.50	0.57	0.64	0.69	0.80	0.96	1.10	1.23
4.0	0.20	0.20	0.20	0.20	0.20	0.26	0.38	0.47	0.55	0.68	0.79	0.89	0.98	1.14	1.42	1.65	1.86
5.0	0.23	0.23	0.23	0.23	0.23	0.31	0.46	0.58	0.68	0.86	1.02	1.16	1.28	1.51	1.91	2.25	2.55
6.0	0.26	0.26	0.26	0.26	0.26	0.36	0.54	0.69	0.82	1.05	1.25	1.43	1.60	1.90	2.43	2.89	3.30
8.0	0.32	0.32	0.32	0.32	0.32	0.45	0.70	0.91	1.10	1.43	1.72	1.99	2.24	2.70	3.52	4.24	4.91
10.0	0.35	0.37	0.38	0.39	0.40	0.57	0.91	1.20	1.46	1.92	2.34	2.72	3.09	3.75	4.95	6.03	7.02
12.0	0.36	0.41	0.45	0.47	0.49	0.71	1.15	1.54	1.88	2.51	3.07	3.60	4.09	5.01	6.67	8.17	9.57
14.0	0.38	0.45	0.51	0.55	0.58	0.85	1.40	1.87	2.31	3.09	3.81	4.48	5.11	6.30	8.45	10.40	12.23
16.0	0.39	0.49	0.56	0.62	0.67	0.98	1.64	2.21	2.73	3.68	4.56	5.37	6.15	7.60	10.26	12.69	14.96
20.0	0.41	0.56	0.67	0.76	0.84	1.24	2.10	2.86	3.57	4.85	6.04	7.16	8.23	10.24	13.94	17.35	20.57
25.0	0.45	0.64	0.80	0.93	1.04	1.56	2.67	3.67	4.59	6.30	7.88	9.38	10.81	13.53	18.57	23.24	27.66
30.0	0.48	0.72	0.91	1.08	1.24	1.86	3.22	4.44	5.58	7.70	9.67	11.55	13.35	16.77	23.14	29.07	34.71
40.0	0.53	0.85	1.13	1.37	1.59	2.41	4.24	5.89	7.44	10.35	13.07	15.67	18.17	22.95	31.89	40.29	48.29
50.0	0.58	0.97	1.31	1.62	1.91	2.91	5.16	7.20	9.13	12.75	16.16	19.42	22.57	28.60	39.95	50.63	60.84
60.0	0.63	1.07	1.47	1.84	2.19	3.36	5.97	8.37	10.63	14.89	18.92	22.78	26.51	33.67	47.18	59.93	72.15

Table 10A-2
LS Factors for Construction Sites
Reference: USDA, Agricultural Handbook No. 703 (1996)

Rock Check Dam Depth	Items	Ditch Foreslope 2:1				Ditch Foreslope 3:1				Ditch Foreslope 4:1				Ditch Foreslope 6:1			
		Ditch Backslope				Ditch Backslope				Ditch Backslope				Ditch Backslope			
		2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1
1.5	Stone[1]																
	Riprap[2]	6.1	7.6	9.1	12.2	7.6	9.1	10.6	13.7	9.1	10.6	12.2	15.2	12.2	13.7	15.2	18.2
	Geo[3]	13.3	16.7	20.0	26.7	16.7	20.0	23.3	30.0	20.0	23.3	26.7	33.3	26.7	30.0	33.3	40.0
2.0	Stone[1]																
	Riprap[2]	10.1	12.6	15.2	20.2	12.6	15.2	17.7	22.8	15.2	17.7	20.2	25.3	20.2	22.8	25.3	30.3
	Geo[3]	18.0	22.5	27.0	36.0	22.5	27.0	31.5	40.5	27.0	31.5	36.0	45.0	36.0	40.5	45.0	54.0
2.5	Stone[1]																
	Riprap[2]	15.5	19.4	23.3	31.1	19.4	23.3	27.2	35.0	23.3	27.2	31.1	38.8	31.1	35.0	38.8	46.6
	Geo[3]	23.3	29.2	35.0	46.7	29.2	35.0	40.8	52.5	35.0	40.8	46.7	58.3	46.7	52.5	58.3	70.0
3.0	Stone[1]																
	Riprap[2]	22.6	28.2	33.8	45.1	28.2	33.8	39.5	50.8	33.8	39.5	45.1	56.4	45.1	50.8	56.4	67.7
	Geo[3]	29.3	36.7	44.0	58.7	36.7	44.0	51.3	66.0	44.0	51.3	58.7	73.3	58.7	66.0	73.3	88.0

[1]Mineral Aggregate (Size 57), Ton, Item number 303-10.01 (n/a for Rock Check Dam)

[2]Machined Rip-Rap (Class A-1), Ton, Item number 709-05.06

[3]Geotextile (Type III) (Erosion Control), S.Y., Item number 740-10.03

Table 10A-3
Typical Rock Check Dam Quantities
V-Ditch
(Quantities have been rounded)

Rock Check Dam Depth	Items	Ditch Foreslope 2:1				Ditch Foreslope 3:1				Ditch Foreslope 4:1				Ditch Foreslope 6:1			
		Ditch Backslope				Ditch Backslope				Ditch Backslope				Ditch Backslope			
		2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1
1.5	Stone[1]																
	Riprap[2]	8.6	10.1	11.6	14.7	10.1	11.6	13.2	16.2	11.6	13.2	14.7	17.7	14.7	16.2	17.7	20.8
	Geo[3]	16.7	20.0	23.3	30.0	20.0	23.3	26.7	33.3	23.3	26.7	30.0	36.7	30.0	33.3	36.7	43.3
2.0	Stone[1]																
	Riprap[2]	13.8	16.3	18.9	23.9	16.3	18.9	21.4	26.4	18.9	21.4	23.9	29.0	23.9	26.4	29.0	34.0
	Geo[3]	22.0	26.5	31.0	40.0	26.5	31.0	35.5	44.5	31.0	35.5	40.0	49.0	40.0	44.5	49.0	58.0
2.5	Stone[1]																
	Riprap[2]	20.6	24.5	28.4	36.1	24.5	28.4	32.2	40.0	28.4	32.2	36.1	43.9	36.1	40.0	43.9	51.7
	Geo[3]	28.0	33.8	39.7	51.3	33.8	39.7	45.5	57.2	39.7	45.5	51.3	63.0	51.3	57.2	63.0	74.7
3.0	Stone[1]																
	Riprap[2]	29.2	34.8	40.4	51.7	34.8	40.4	46.1	57.4	40.4	46.1	51.7	63.0	51.7	57.4	63.0	74.3
	Geo[3]	34.7	42.0	49.3	64.0	42.0	49.3	56.7	71.3	49.3	56.7	64.0	78.7	64.0	71.3	78.7	93.3

[1]Mineral Aggregate (Size 57), Ton, Item number 303-10.01 (n/a for Rock Check Dam)
[2]Machined Rip-Rap (Class A-1), Ton, Item number 709-05.06
[3]Geotextile (Type III) (Erosion Control), S.Y., Item number 740-10.03

Table 10A-4
Typical Rock Check Dam Quantities
Ditch Width = 2 feet
(Quantities have been rounded)

Rock Check Dam Depth	Items	Ditch Foreslope 2:1				Ditch Foreslope 3:1				Ditch Foreslope 4:1				Ditch Foreslope 6:1			
		Ditch Backslope				Ditch Backslope				Ditch Backslope				Ditch Backslope			
		2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1
1.5	Stone[1]																
	Riprap[2]	11.1	12.7	14.2	17.2	12.7	14.2	15.7	18.7	14.2	15.7	17.2	20.2	17.2	18.7	20.2	23.3
	Geo[3]	20.0	23.3	26.7	33.3	23.3	26.7	30.0	36.7	26.7	30.0	33.3	40.0	33.3	36.7	40.0	46.7
2.0	Stone[1]																
	Riprap[2]	17.5	20.0	22.6	27.6	20.0	22.6	25.1	30.1	22.6	25.1	27.6	32.7	27.6	30.1	32.7	37.7
	Geo[3]	26.0	30.5	35.0	44.0	30.5	35.0	39.5	48.5	35.0	39.5	44.0	53.0	44.0	48.5	53.0	62.0
2.5	Stone[1]																
	Riprap[2]	25.7	29.5	33.4	41.2	29.5	33.4	37.3	45.1	33.4	37.3	41.2	49.0	41.2	45.1	49.0	56.7
	Geo[3]	32.7	38.5	44.3	56.0	38.5	44.3	50.2	61.8	44.3	50.2	56.0	67.7	56.0	61.8	67.7	79.3
3.0	Stone[1]																
	Riprap[2]	35.8	41.4	47.1	58.3	41.4	47.1	52.7	64.0	47.1	52.7	58.3	69.6	58.3	64.0	69.6	80.9
	Geo[3]	40.0	47.3	54.7	69.3	47.3	54.7	62.0	76.7	54.7	62.0	69.3	84.0	69.3	76.7	84.0	98.7

[1] Mineral Aggregate (Size 57), Ton, Item number 303-10.01 (n/a for Rock Check Dam)
[2] Machined Rip-Rap (Class A-1), Ton, Item number 709-05.06
[3] Geotextile (Type III) (Erosion Control), S.Y., Item number 740-10.03

Table 10A-5
Typical Rock Check Dam Quantities
Ditch Width = 4 feet
(Quantities have been rounded)

Rock Check Dam Depth	Items	Ditch Foreslope 2:1				Ditch Foreslope 3:1				Ditch Foreslope 4:1				Ditch Foreslope 6:1			
		Ditch Backslope				Ditch Backslope				Ditch Backslope				Ditch Backslope			
		2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1
1.5	Stone[1]																
	Riprap[2]	13.7	15.2	16.7	19.7	15.2	16.7	18.2	21.3	16.7	18.2	19.7	22.8	19.7	21.3	22.8	25.8
	Geo[3]	23.3	26.7	30.0	36.7	26.7	30.0	33.3	40.0	30.0	33.3	36.7	43.3	36.7	40.0	43.3	50.0
2.0	Stone[1]																
	Riprap[2]	21.2	23.7	26.3	31.3	23.7	26.3	28.8	33.8	26.3	28.8	31.3	36.4	31.3	33.8	36.4	41.4
	Geo[3]	30.0	34.5	39.0	48.0	34.5	39.0	43.5	52.5	39.0	43.5	48.0	57.0	48.0	52.5	57.0	66.0
2.5	Stone[1]																
	Riprap[2]	30.7	34.6	38.5	46.2	34.6	38.5	42.4	50.1	38.5	42.4	46.2	54.0	46.2	50.1	54.0	61.8
	Geo[3]	37.3	43.2	49.0	60.7	43.2	49.0	54.6	66.5	49.0	54.8	60.7	72.3	60.7	66.5	72.3	84.0
3.0	Stone[1]																
	Riprap[2]	42.4	48.0	53.7	64.9	48.0	53.7	59.3	70.6	53.7	59.3	64.9	76.2	64.9	70.6	76.2	87.5
	Geo[3]	45.3	52.7	60.0	74.7	52.7	60.0	67.3	82.0	60.0	67.3	74.7	89.3	74.7	82.0	89.3	104

[1] Mineral Aggregate (Size 57), Ton, Item number 303-10.01 (n/a for Rock Check Dam)
[2] Machined Rip-Rap (Class A-1), Ton, Item number 709-05.06
[3] Geotextile (Type III) (Erosion Control), S.Y., Item number 740-10.03

Table 10A-6
Typical Rock Check Dam Quantities
Ditch Width = 6 feet
(Quantities have been rounded)

Rock Check Dam Depth	Items	Ditch Foreslope 2:1				Ditch Foreslope 3:1				Ditch Foreslope 4:1				Ditch Foreslope 6:1			
		Ditch Backslope				Ditch Backslope				Ditch Backslope				Ditch Backslope			
		2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1
1.5	Stone[1]																
	Riprap[2]	16.2	17.7	19.2	22.3	17.7	19.2	20.7	23.8	19.2	20.7	22.3	25.3	22.3	23.8	25.3	28.3
	Geo[3]	26.7	30.0	33.3	40.0	30.0	33.3	36.7	43.3	33.3	36.7	40.0	46.7	40.0	43.3	46.7	53.3
2.0	Stone[1]																
	Riprap[2]	24.9	27.4	29.9	35.0	27.4	29.9	32.5	37.5	29.9	32.5	35.0	40.1	35.0	37.5	40.1	45.1
	Geo[3]	34.0	38.5	43.0	52.0	38.5	43.0	47.5	56.5	43.0	47.5	52.0	61.0	52.0	56.5	61.0	70.0
2.5	Stone[1]																
	Riprap[2]	35.8	39.6	43.5	51.3	39.6	43.5	47.4	55.2	43.5	47.4	51.3	59.1	51.3	55.2	59.1	66.8
	Geo[3]	42.0	47.8	53.7	65.3	47.8	53.7	59.5	71.2	53.7	59.5	65.3	77.0	65.3	71.2	77.0	88.7
3.0	Stone[1]																
	Riprap[2]	49.0	54.6	60.3	71.6	54.6	60.3	65.9	77.2	60.3	65.9	71.6	82.8	71.6	77.2	82.8	94.1
	Geo[3]	50.7	58.0	65.3	80.0	58.0	65.3	72.7	87.3	65.3	72.7	80.0	94.7	80.0	87.3	94.7	109

[1] Mineral Aggregate (Size 57), Ton, Item number 303-10.01 (n/a for Rock Check Dam)
[2] Machined Rip-Rap (Class A-1), Ton, Item number 709-05.06
[3] Geotextile (Type III) (Erosion Control), S.Y., Item number 740-10.03

Table 10A-7
Typical Rock Check Dam Quantities
Ditch Width = 8 feet
(Quantities have been rounded)

Enhanced Check Dam Depth	Items	Ditch Foreslope 2:1				Ditch Foreslope 3:1				Ditch Foreslope 4:1				Ditch Foreslope 6:1			
		Ditch Backslope				Ditch Backslope				Ditch Backslope				Ditch Backslope			
		2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1
1.5	Stone[1]	0.10	0.13	0.16	0.21	0.13	0.16	0.18	0.23	0.16	0.18	0.21	0.26	0.21	0.23	0.26	0.31
	Riprap[2]	6.1	7.6	9.1	12.2	7.6	9.1	10.6	13.7	9.1	10.6	12.2	15.2	12.2	13.7	15.2	18.2
	Geo[3]	15.8	19.8	23.8	31.7	19.8	23.8	27.7	35.6	23.8	27.7	31.7	39.6	31.7	35.6	39.6	47.5
2.0	Stone[1]	0.17	0.21	0.25	0.33	0.21	0.25	0.29	0.37	0.25	0.29	0.33	0.41	0.33	0.37	0.41	0.50
	Riprap[2]	10.1	12.6	15.2	20.2	12.6	15.2	17.7	22.8	15.2	17.7	20.2	25.3	20.2	22.8	25.3	30.3
	Geo[3]	22.0	27.5	33.0	44.0	27.5	33.0	38.5	49.5	33.0	38.5	44.0	55.0	44.0	49.5	55.0	66.0
2.5	Stone[1]	0.24	0.30	0.36	0.48	0.30	0.36	0.42	0.54	0.36	0.42	0.48	0.60	0.48	0.54	0.60	0.72
	Riprap[2]	15.5	19.4	23.3	31.1	19.4	23.3	27.2	35.0	23.3	27.2	31.1	38.8	31.1	35.0	38.8	46.6
	Geo[3]	29.2	36.5	43.8	58.3	36.5	43.8	51.0	65.6	43.8	51.0	58.3	72.9	58.3	65.6	72.9	87.5
3.0	Stone[1]	0.33	0.41	0.50	0.66	0.41	0.50	0.58	0.75	0.50	0.58	0.66	0.83	0.66	0.75	0.83	0.99
	Riprap[2]	22.6	28.2	33.8	45.1	28.2	33.8	39.5	50.8	33.8	39.5	45.1	56.4	45.1	50.8	56.4	67.7
	Geo[3]	37.3	46.7	56.0	74.7	46.7	56.0	65.3	84.0	56.0	65.3	74.7	93.3	74.7	84.0	93.3	112

[1] Mineral Aggregate (Size 57), Ton, Item number 303-10.01
[2] Machined Rip-Rap (Class A-1), Ton, Item number 709-05.06
[3] Geotextile (Type III) (Erosion Control), S.Y., Item number 740-10.03

Table 10A-8
Typical Enhanced Rock Check Dam Quantities
V-Ditch
(Quantities have been rounded)

Enhanced Check Dam Depth	Items	Ditch Foreslope 2:1				Ditch Foreslope 3:1				Ditch Foreslope 4:1				Ditch Foreslope 6:1			
		Ditch Backslope				Ditch Backslope				Ditch Backslope				Ditch Backslope			
		2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1
1.5	Stone[1]	0.14	0.17	0.20	0.25	0.17	0.20	0.22	0.27	0.20	0.22	0.25	0.30	0.25	0.27	0.30	0.35
	Riprap[2]	8.6	10.1	11.6	14.7	10.1	11.6	13.2	16.2	11.6	13.2	14.7	17.7	14.7	16.2	17.7	20.8
	Geo[3]	20.2	24.1	28.1	36.0	24.1	28.1	32.0	40.0	28.1	32.0	36.0	43.9	36.0	40.0	43.9	51.8
2.0	Stone[1]	0.22	0.26	0.30	0.39	0.26	0.30	0.34	0.43	0.30	0.34	0.39	0.47	0.39	0.43	0.47	0.55
	Riprap[2]	13.8	16.3	18.9	23.9	16.3	18.9	21.4	26.4	18.9	21.4	23.9	29.0	23.9	26.4	29.0	34.0
	Geo[3]	27.3	32.8	38.3	49.3	32.8	38.3	43.8	54.8	38.3	43.8	49.3	60.3	49.3	54.8	60.3	71.3
2.5	Stone[1]	0.31	0.37	0.43	0.55	0.37	0.43	0.49	0.61	0.43	0.49	0.55	0.67	0.55	0.61	0.67	0.79
	Riprap[2]	20.6	24.5	28.4	36.1	24.5	28.4	32.2	40.0	28.4	32.2	36.1	43.9	36.1	40.0	43.9	51.7
	Geo[3]	35.5	42.8	50.1	64.7	42.8	50.1	57.4	72.0	50.1	57.4	64.7	79.3	64.7	72.0	79.3	93.8
3.0	Stone[1]	0.41	0.50	0.58	0.75	0.50	0.58	0.66	0.83	0.58	0.66	0.75	0.91	0.75	0.83	0.91	1.08
	Riprap[2]	29.2	34.8	40.4	51.7	34.8	40.4	46.1	57.4	40.4	46.1	51.7	63.0	51.7	57.4	63.0	74.3
	Geo[3]	44.7	54.0	63.3	82.0	54.0	63.3	72.7	91.3	63.3	72.7	82.0	101	82.0	91.3	101	119

[1]Mineral Aggregate (Size 57), Ton, Item number 303-10.01
[2]Machined Rip-Rap (Class A-1), Ton, Item number 709-05.06
[3]Geotextile (Type III) (Erosion Control), S.Y., Item number 740-10.03

Table 10A-9
Typical Enhanced Rock Check Dam Quantities
Ditch Width = 2 feet
(Quantities have been rounded)

Enhanced Check Dam Depth	Items	Ditch Foreslope 2:1				Ditch Foreslope 3:1				Ditch Foreslope 4:1				Ditch Foreslope 6:1			
		Ditch Backslope				Ditch Backslope				Ditch Backslope				Ditch Backslope			
		2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1
1.5	Stone[1]	0.19	0.21	0.24	0.29	0.21	0.24	0.26	0.32	0.24	0.26	0.29	0.34	0.29	0.32	0.34	0.39
	Riprap[2]	11.1	12.7	14.2	17.2	12.7	14.2	15.7	18.7	14.2	15.7	17.2	20.2	17.2	18.7	20.2	23.3
	Geo[3]	24.5	28.5	32.4	40.3	28.5	32.4	36.4	44.3	32.4	36.4	40.3	48.3	40.3	44.3	48.3	56.2
2.0	Stone[1]	0.28	0.32	0.36	0.44	0.32	0.36	0.40	0.48	0.36	0.40	0.44	0.52	0.44	0.48	0.52	0.61
	Riprap[2]	17.5	20.0	22.6	27.6	20.0	22.6	25.1	30.1	22.6	25.1	27.6	32.7	27.6	30.1	32.7	37.7
	Geo[3]	32.7	38.2	43.7	54.7	38.2	43.7	49.2	60.2	43.7	49.2	54.7	65.7	54.7	60.2	65.7	76.7
2.5	Stone[1]	0.38	0.44	0.50	0.62	0.44	0.50	0.56	0.68	0.50	0.56	0.62	0.74	0.62	0.68	0.74	0.86
	Riprap[2]	25.7	29.5	33.4	41.2	29.5	33.4	37.3	45.1	33.4	37.3	41.2	49.0	41.2	45.1	49.0	56.7
	Geo[3]	41.8	49.1	56.4	71.0	49.1	56.4	63.7	78.3	56.4	63.7	71.0	85.6	71.0	78.3	85.6	100
3.0	Stone[1]	0.50	0.58	0.66	0.83	0.58	0.66	0.75	0.91	0.66	0.75	0.83	0.99	0.83	0.91	0.99	1.16
	Riprap[2]	35.8	41.4	47.1	58.3	41.4	47.1	52.7	64.0	47.1	52.7	58.3	69.6	58.3	64.0	69.6	80.9
	Geo[3]	52.0	61.3	70.7	89.3	61.3	70.7	80.0	98.7	70.7	80.0	89.3	108	89.3	98.7	108	127

[1]Mineral Aggregate (Size 57), Ton, Item number 303-10.01
[2]Machined Rip-Rap (Class A-1), Ton, Item number 709-05.06
[3]Geotextile (Type III) (Erosion Control), S.Y., Item number 740-10.03

Table 10A-10
Typical Enhanced Rock Check Dam Quantities
Ditch Width = 4 feet
(Quantities have been rounded)

Enhanced Check Dam Depth	Items	Ditch Foreslope 2:1				Ditch Foreslope 3:1				Ditch Foreslope 4:1				Ditch Foreslope 6:1			
		Ditch Backslope				Ditch Backslope				Ditch Backslope				Ditch Backslope			
		2:1	**3:1**	**4:1**	**6:1**	**2:1**	**3:1**	**4:1**	**6:1**	**2:1**	**3:1**	**4:1**	**6:1**	**2:1**	**3:1**	**4:1**	**6:1**
1.5	Stone[1]	0.23	0.25	0.28	0.33	0.25	0.28	0.31	0.36	0.28	0.31	0.33	0.38	0.33	0.36	0.38	0.43
	Riprap[2]	13.7	15.2	16.7	19.7	15.2	16.7	18.2	21.3	16.7	18.2	19.7	22.8	19.7	21.3	22.8	25.8
	Geo[3]	28.8	32.8	36.8	44.7	32.8	36.8	40.7	48.6	36.8	40.7	44.7	52.6	44.7	48.6	52.6	60.5
2.0	Stone[1]	0.33	0.37	0.41	0.50	0.37	0.41	0.46	0.54	0.41	0.46	0.50	0.58	0.50	0.54	0.58	0.66
	Riprap[2]	21.2	23.7	26.3	31.3	23.7	26.3	28.8	33.8	26.3	28.8	31.3	36.4	31.3	33.8	36.4	41.4
	Geo[3]	38.0	43.5	49.0	60.0	43.5	49.0	54.5	65.5	49.0	54.5	60.0	71.0	60.0	65.5	71.0	82.0
2.5	Stone[1]	0.45	0.51	0.57	0.69	0.51	0.57	0.63	0.75	0.57	0.63	0.69	0.81	0.69	0.75	0.81	0.93
	Riprap[2]	30.7	34.6	38.5	46.2	34.6	38.5	42.4	50.1	38.5	42.4	46.2	54.0	46.2	50.1	54.0	61.8
	Geo[3]	48.2	55.5	62.8	77.3	55.5	62.8	70.0	84.6	62.8	70.0	77.3	91.9	77.3	84.6	91.9	107
3.0	Stone[1]	0.58	0.66	0.75	0.91	0.66	0.75	0.83	0.99	0.75	0.83	0.91	1.08	0.91	0.99	1.08	1.24
	Riprap[2]	42.4	48.0	53.7	64.9	48.0	53.7	59.3	70.6	53.7	59.3	64.9	76.2	64.9	70.6	76.2	87.5
	Geo[3]	59.3	68.7	78.0	96.7	68.7	78.0	87.3	106	78.0	87.3	96.7	115	96.7	106	115	134

[1] Mineral Aggregate (Size 57), Ton, Item number 303-10.01
[2] Machined Rip-Rap (Class A-1), Ton, Item number 709-05.06
[3] Geotextile (Type III) (Erosion Control), S.Y., Item number 740-10.03

Table 10A-11
Typical Enhanced Rock Check Dam Quantities
Ditch Width = 6 feet
(Quantities have been rounded)

Enhanced Check Dam Depth	Items	Ditch Foreslope 2:1				Ditch Foreslope 3:1				Ditch Foreslope 4:1				Ditch Foreslope 6:1			
		Ditch Backslope				Ditch Backslope				Ditch Backslope				Ditch Backslope			
		2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1	2:1	3:1	4:1	6:1
1.5	Stone[1]	0.27	0.29	0.32	0.37	0.29	0.32	0.35	0.40	0.32	0.35	0.37	0.42	0.37	0.40	0.42	0.48
	Riprap[2]	16.2	17.7	19.2	22.3	17.7	19.2	20.7	23.8	19.2	20.7	22.3	25.3	22.3	23.8	25.3	28.3
	Geo[3]	33.2	37.1	41.1	49.0	37.1	41.1	45.0	53.0	41.1	45.0	49.0	56.9	49.0	53.0	56.9	64.8
2.0	Stone[1]	0.39	0.43	0.47	0.55	0.43	0.47	0.51	0.59	0.47	0.51	0.55	0.63	0.55	0.59	0.63	0.72
	Riprap[2]	24.9	27.4	29.9	35.0	27.4	29.9	32.5	37.5	29.9	32.5	35.0	40.1	35.0	37.5	40.1	45.1
	Geo[3]	39.3	44.8	50.3	61.3	44.8	50.3	55.8	66.8	50.3	55.8	61.3	72.3	61.3	66.8	72.3	83.3
2.5	Stone[1]	0.52	0.58	0.64	0.76	0.58	0.64	0.70	0.82	0.64	0.70	0.76	0.88	0.76	0.82	0.88	1.00
	Riprap[2]	35.8	39.6	43.5	51.3	39.6	43.5	47.4	55.2	43.5	47.4	51.3	59.1	51.3	55.2	59.1	66.8
	Geo[3]	46.5	53.8	61.1	75.7	53.8	61.1	68.4	83.0	61.1	68.4	75.7	90.3	75.7	83.0	90.3	105
3.0	Stone[1]	0.66	0.75	0.83	0.99	0.75	0.83	0.91	1.08	0.83	0.91	0.99	1.16	0.99	1.08	1.16	1.32
	Riprap[2]	49.0	54.6	60.3	71.6	54.6	60.3	65.9	77.2	60.3	65.9	71.6	82.8	71.6	77.2	82.8	94.1
	Geo[3]	54.7	64.0	73.3	92.0	64.0	73.3	82.7	101	73.3	82.7	92.0	111	92.0	101	111	129

[1] Mineral Aggregate (Size 57), Ton, Item number 303-10.01

[2] Machined Rip-Rap (Class A-1), Ton, Item number 709-05.06

[3] Geotextile (Type III) (Erosion Control), S.Y., Item number 740-10.03

Table 10A-12
Typical Enhanced Rock Check Dam Quantities
Ditch Width = 8 feet
(Quantities have been rounded)

Required Pipe Size (inches)	Two-Pipe Alternate (inches)	Three-Pipe Alternate (inches)
18	15, 15	-
24	18, 18	15, 15, 18
30	24, 24	18, 18, 24
36	24, 30	18, 24, 24
42	30, 36	24, 24, 30
48	36, 36	30, 30, 30
54	36, 42	30, 36, 36
60	42, 42	36, 36, 36
72	48, 48	36, 42, 42
84	48, 54	42, 42, 48

Table 10A-13
Multiple-Pipe Alternates for Temporary Culvert Crossings
See TDOT Standard Drawing EC-STR-32

10.09.2 EXAMPLE PROBLEMS

10.09.2.1 EXAMPLE PROBLEM: ESTIMATING SOIL LOSS USING RUSLE2

INTRODUCTION:

As described in Section 10.07, RUSLE2 is a Windows™ based software package which may be used to estimate soil erosion rates. It is published by the Agricultural Research Service (ARS) of the USDA. The purpose of this problem is to provide an example of how RUSLE2 could be used to analyze a particular design situation, but not to provide a tutorial on the use of the program. Rather, this problem will demonstrate only a small part of the program's capabilities.

RUSLE2 is an extremely flexible tool which is able to account for nearly all of the variables which may affect erosion rates, as described in Section 10.03. In addition, it is capable of analyzing either annual averages or daily time-series data and can be applied to a huge variety of "real-world" situations. The key to its flexibility is its use of data input "templates" which allow the user to control the complexity of the analysis as well as which variables will be considered. The program offers a number of predefined templates which may be used "off the shelf" and also allows the user to define custom templates. This example problem will utilize a few of the predefined templates.

The RUSLE2 package also provides a database of rainfall data at specific locations across the nation. The user has the option of selecting predefined data for a location near the project site or entering custom rainfall data. This example problem will use the predefined database.

GIVEN:

A roadway reconstruction project is proposed for a 2-lane highway in Putnam County, near Cookeville. The project will include the realignment and re-grading of the highway as well as complete pavement replacement. The new roadway will consist of two 12-foot travel lanes with 10-foot shoulders and will have side ditches on both sides. A sediment basin (see Section 10.08.2) is proposed to serve a 1250-foot long segment of the project.

Proceeding from left to right, a representative cross section of the roadway in this area would consist of the following elements:

- 4H:1V backslope on the left side ditch, at a horizontal distance of 18 feet
- 6H:1V foreslope on the left side ditch, at a horizontal distance of 21 feet
- 10-foot shoulder at 4%
- two 12-foot travel lanes at 2% (normal crown)
- 10-foot shoulder at 4%
- 20-foot wide clear zone at a slope of 6H:1V
- 4H:1V foreslope on the right side ditch at a horizontal distance of 18 feet
- 4H:1V backslope on the right side ditch at a horizontal distance of 28 feet

Off site flows will be diverted away from the project area with diversion berms.

FIND:

Use the RUSLE2 program to estimate how frequently it will be necessary to remove the accumulated sediments from the sediment basin.

SOLUTION:

Step 1: **Divide the Roadway Cross Section into Separate Elements**

To estimate the total annual sediment load produced from the site, it will be necessary to divide the cross section into separate identifiable slope elements so that the erosion from each slope can be identified. Thus, the cross section is divided into the following elements:

- **slope element A** includes the backslope of the left side ditch
- **slope element B** includes the slope from the crown of the roadway to the toe of the foreslope of the left side ditch
- **slope element C** includes the slope from the crown of the roadway to the toe of the foreslope of the right side ditch
- **slope element D** includes the backslope of the right side ditch

Step 2: **Determine the Area Covered by Each Slope Element**

Since RUSLE2 yields erosion rates in tons/acre/year, it is necessary to compute the area represented by each of the four slope elements so that the erosion rates can be determined in terms of tons/year. These areas can be computed by multiplying the length of each slope by the length of the site, which is 1250 feet. The lengths of slopes 6H:1V and steeper will be determined based upon the actual slope length, accounting for both the horizontal and vertical distances. Flatter slope lengths will be based simply on the horizontal distance. Thus:

$$Area\ A = (18.55\ feet) \times (1250\ feet) \times \left(\frac{1\ acre}{43{,}560\ feet} \right) = 0.532\ \text{acres}$$

$$Area\ B = (21.29 + 10 + 12\ feet) \times (1250\ feet) \times \left(\frac{1\ acre}{43{,}560\ feet} \right) = 1.242\ \text{acres}$$

$$Area\ C = (20.28 + 18.55 + 10 + 12\ feet) \times (1250\ feet) \times \left(\frac{1\ acre}{43{,}560\ feet} \right) = 1.745\ \text{acres}$$

$$Area\ D = (28.86\ feet) \times (1250\ feet) \times \left(\frac{1\ acre}{43{,}560\ feet} \right) = 0.828\ \text{acres}$$

Adding these four areas together yields a total site area of 4.348 acres.

Step 3: **Estimate Erosion Rates from each Slope Element**

RUSLE2 may now be used to estimate erosion rates for each of the four slope elements, starting with element A. Upon starting the program, the user is presented with the startup screen shown in Figure 10A-6, which allows the user to select an input data template. Because slope element A is a simple, uniform slope with a single surface condition, the analysis will be performed at the "profile" level using the "ARS Basic Uniform Slope" option. The selection of these options is illustrated in the figure.

Once the basic template has been selected, the user is usually prompted to open an "object" (when this does not occur, the user may use the "File" menu to open a profile). In normal practice, the user will not create an analysis from scratch. Rather, an appropriate existing object is opened and the data modified as required. In this case, when prompted to open an object, the "Highly Disturbed Land" folder is selected, as shown in Figure 10A-7. Underneath this folder, the "OSM Manual Exercises" folder is opened and the "Charleston, SC Base" analysis is selected. This analysis is selected because it represents a uniform slope and thus is a good fit for slope element A.

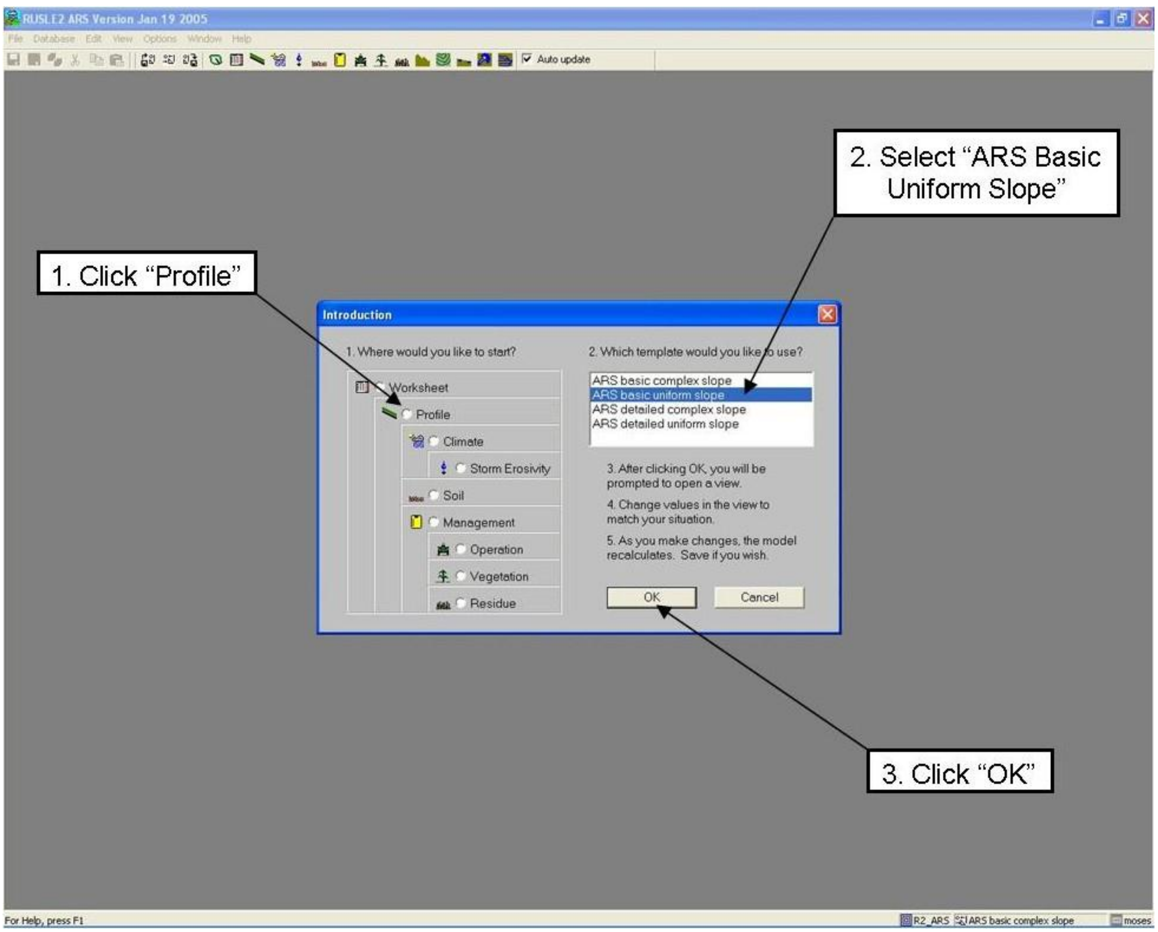


Figure 10A-6
RUSLE2 Start Screen

The analysis opened for Charleston, South Carolina is shown in Figure 10A-8. As can be seen, it consists of five basic steps which are the minimum necessary to estimate the erosion rate on a uniform slope. As the data for each step is updated, the computation results in the lower left corner of the window are automatically updated.

The first task is to update the location. In order to choose the correct location, the "▼" button next to the description of the location is clicked, which opens the database of predefined rainfall information. The database window is scrolled to find the entry for Tennessee, which is found to have four entries. The entry titled "Davidson County Average (Nashville)" is selected, as it is judged that the data at this location will be most similar to the data at the Cookeville site.

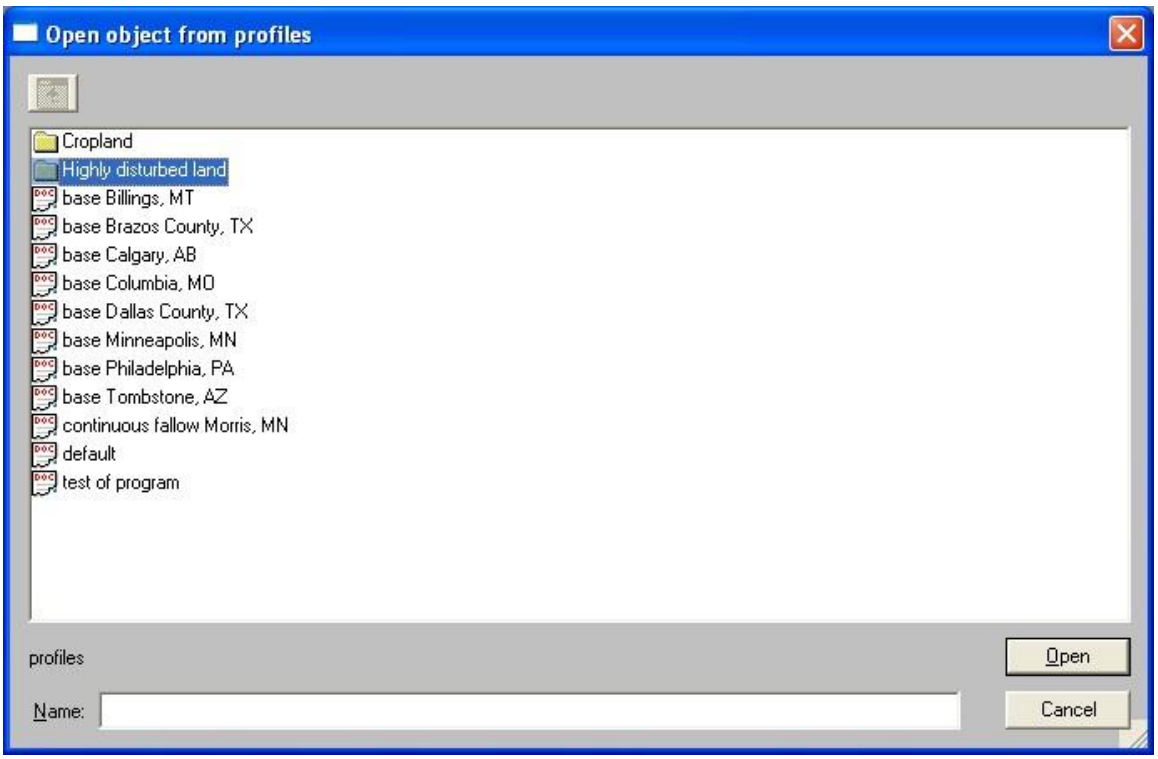


Figure 10A-7
RUSLE 2 Open Object Screen

"Step 2" of the analysis is to select the soil type. As above, the "▼" button next to the soil description is pressed to open a menu of available soil types. Based on the soil types found at this site, the option "Clay Loam (l -m, s perm)" is selected.

"Step 3" of the analysis is to enter the slope length and grade. In this case, a slope length of 18 feet is entered, as the required input is the horizontal slope distance, not the actual distance along the slope. Because slope element A is at a slope of 4H:1V, a value of 25 is entered into the input area for the average slope steepness in percent.

"Step 4" task of the analysis is to select the "management" of the slope, which reflects the condition of the soil surface. A very wide variety of surface conditions are available when the "▼" button is clicked for this step. The selection of an option for this parameter may be very complex, since at different times parts of the surface may be provided with temporary or permanent seeding and other parts may or may not be paved. Although RUSLE2 provides an option for analyzing changing surface conditions over time, such an analysis is beyond the scope of this example. Thus, in order to be conservative, it is assumed that no vegetative cover will be present and the "Blade cut, smooth, bare" option is selected.

Finally, "Step 5" is to select the support practices which will be used on the slope. Of the various options available, the only required entry is for the contouring of the surface. This concept is easily applied to tilled agricultural land; but is more difficult to define for a graded roadway embankment. Thus, the 'Up-and-Down Slope" option is selected to provide a conservative analysis. Because practices such as vegetative strips, flow diversions, etc. will not be used on this slope, the other support practices will be left as "none."

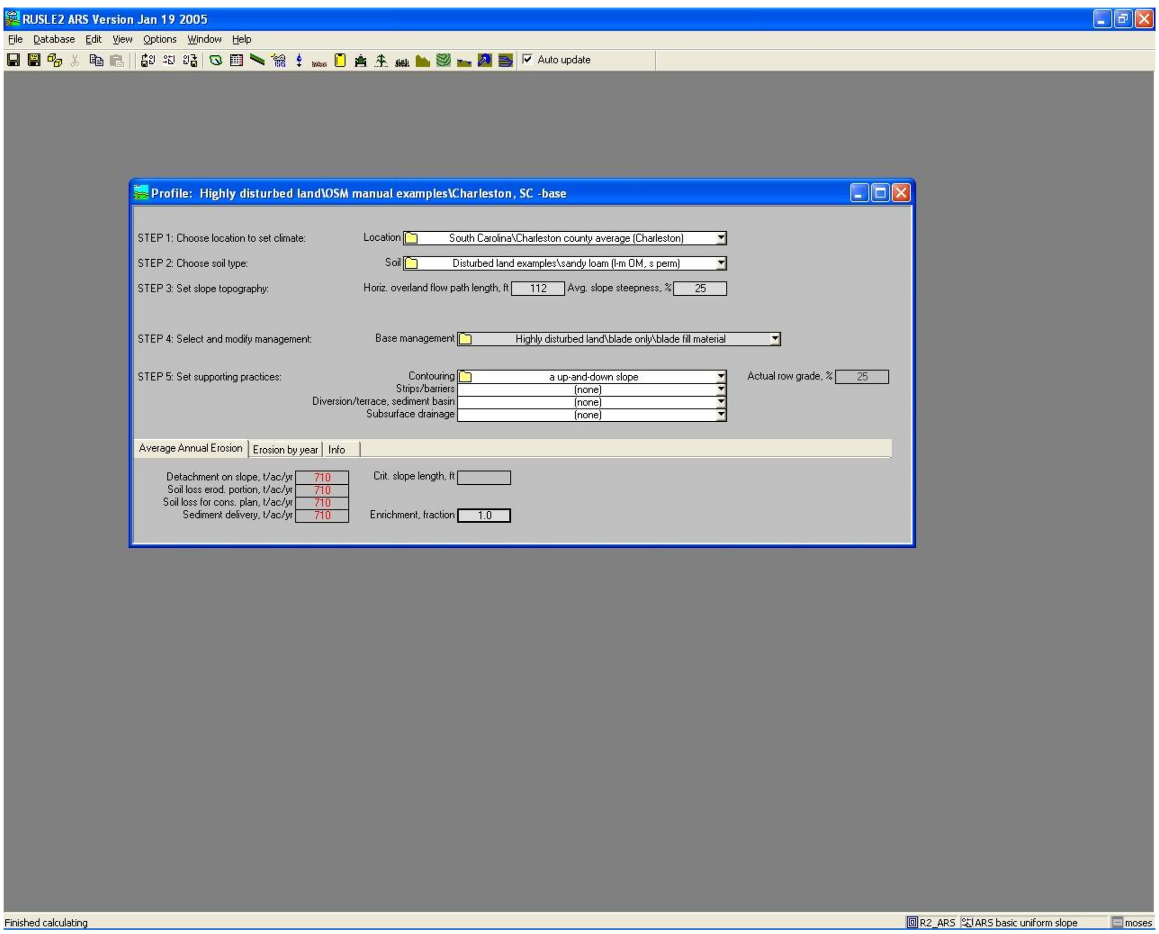


Figure 10A-8
Beginning Point of the Analysis of Slope Element A

Once all five of the data input entries have been completed, it is found that the predicted average erosion from slope element A will be 68 tons/acre/year.

At this point, the data entered into the current analysis is still under the Charleston, South Carolina heading. Thus, to complete the analysis, it is necessary to save the data under another name. Choosing the “Save As” option under the “File” menu opens the “Save Object” dialogue box, which is still “pointing” to the “OSM Manual Exercises” folder. Since this is not an appropriate place to save the data, the  button is clicked, and the data is saved under the “Highly Disturbed Land” folder.

Because slope element D is nearly identical to slope element A, the just-saved data for element A will be the basis for the analysis of element D. The only difference between the two slopes is that the slope distance for element D is 28 feet. Once this has been entered into the input boxes for “Step 3,” the computation is automatically updated to yield 81 tons/acre/year, as shown in Figure 10A-9. As for element A, this data is saved under another name.

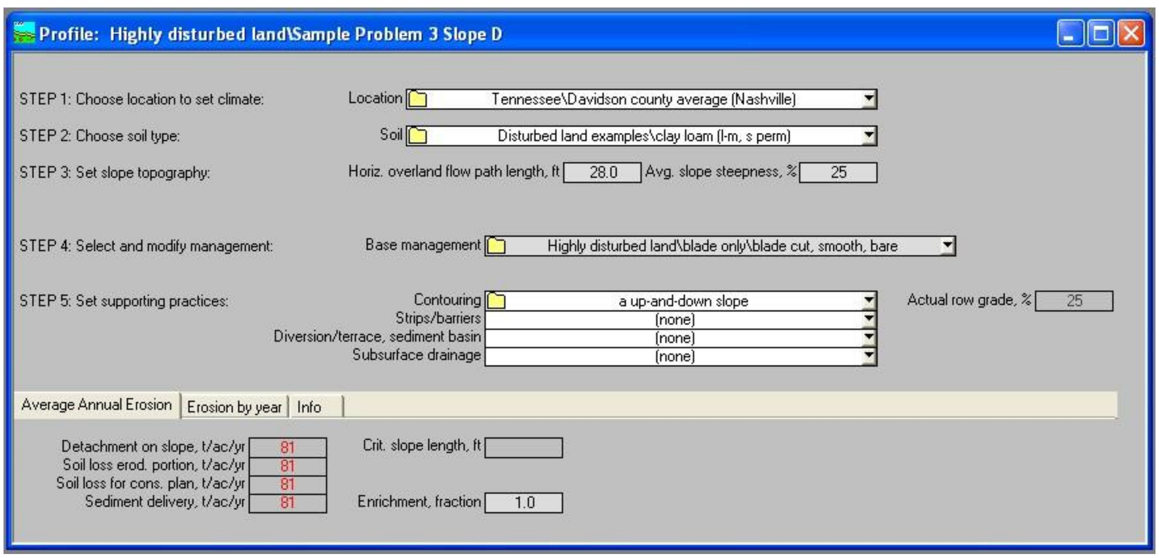


Figure 10A-9
Computation Results for Slope Element D

The remaining two slope elements, B and C, include the travel lanes, shoulders and ditch foreslopes and are thus non-uniform slopes. This makes it necessary to change to a different predefined template, and the simplest means of doing this is to close the program and start it again.

Upon restarting the program, the user is again presented with the start screen shown in Figure 10A-6. As was the case before, the “Profile” option is selected; however, since this analysis is for slope element B, which is non-uniform, the “ARS Basic Complex Slope” option is selected. Navigation through the “Open Object” file structure is the same as was previously described for slope element A. In this case, however, the analysis “Charleston, WV 2 Seg Convex” is selected. This loads the analysis shown in Figure 10A-10.

This analysis template is considerably different from the uniform slope template. It provides a graphical representation of the slope, and instead of providing a simple "step 1" to "step 5" process, it provides tabs which are used to input data as well as to obtain detailed output. Before using these tabs, however, it is necessary to update the location of the analysis. As for the earlier analysis, the "▼" button adjacent to the location description is clicked, and "Davidson County Average (Nashville)" is selected from the options for Tennessee.

The next step is to click on the "Soil" tab, which opens a window where the type of soil may be selected. Again, the "▼" button adjacent to the soil description is clicked, and the "Clay Loam (l -m, s perm)" option is selected.

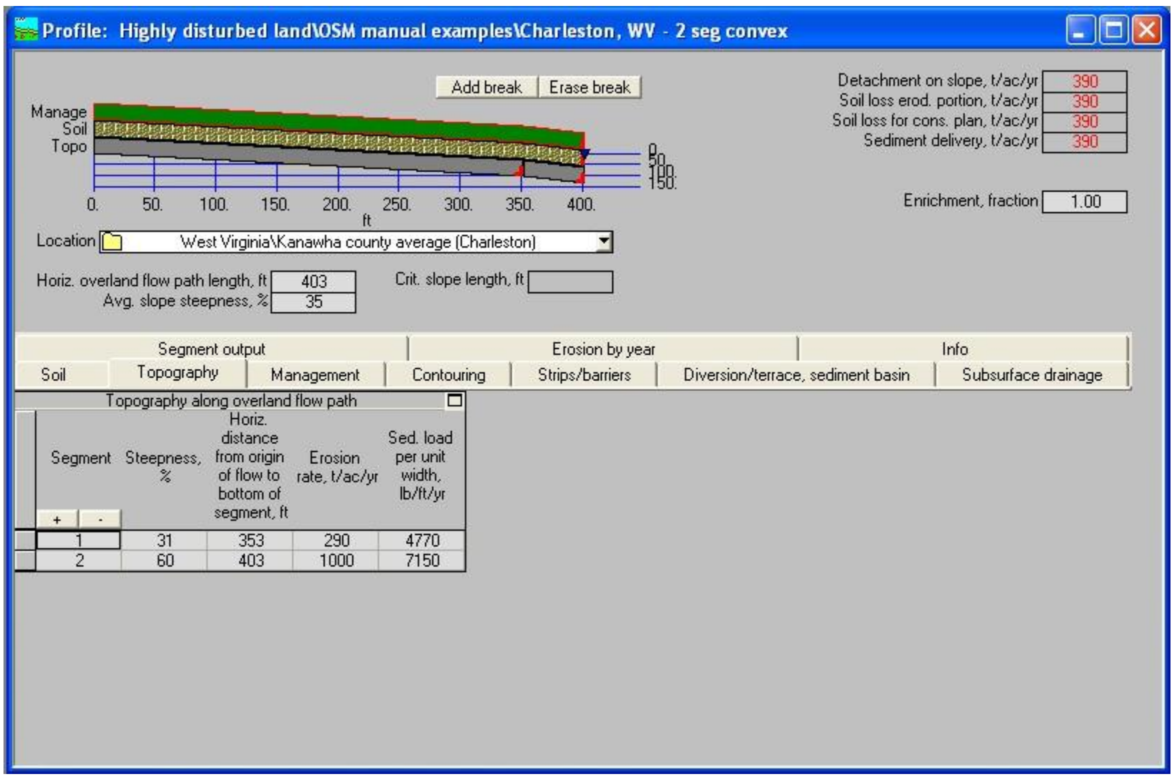


Figure 10A-10
Start of Analysis of Slope Element B

The next tab to be clicked is the "Topography" tab. This opens a window which allows the input of the slope lengths and grades for each segment of the complex slope. Since segment 1 is at the top of the slope, a length of 12 feet and a grade ("Steepness") of 2% are entered for this segment. This will result in a change in the overall length of the slope and this will cause the program to "pop" an error message asking whether the data should be scaled for the new length. This message may be answered by clicking "Yes." Since segment 2 corresponds to the shoulder of the roadway, a slope length of 22 feet and a grade of 4% are entered for this segment (again answering "Yes" to the error message). It should be noted that the slope distances for each segment are cumulative, so that the 22 feet for segment 2 represents 12 feet for the travel lane and 10 feet for the shoulder.

The data template provides only two segments; however, slope element B contains three segments. Thus, another segment must be added. This is accomplished by clicking the "+" button above the segment numbers, which opens up a third line. A slope distance of 43 feet (once again, the cumulative distance) and a grade of 17% (which corresponds to a 6H:1V slope) are entered. As these values are entered for each segment, the graphical representation of the slope at the top of the window is updated automatically. Once this process is complete, the user should review the distances and the grades to ensure that they are correct.

The next tab is the "Management" tab, which allows the basic condition of the soil to be specified. As before, the "▼" button adjacent to the surface description is clicked, and the "Blade cut, smooth, bare" option is selected. The "Contouring" tab is clicked next, and, as was done for the other slopes, the "Up-and-Down Slope" option is selected. The remaining input tabs are not required for this problem.

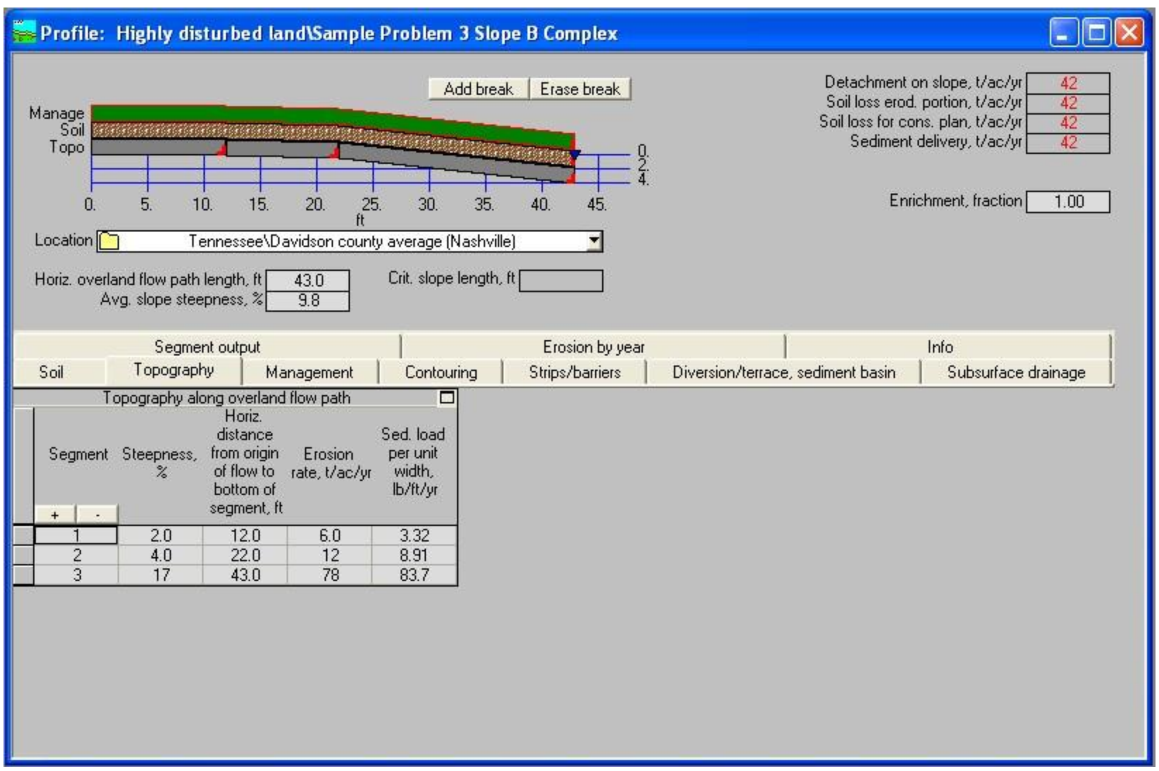


Figure 10A-11
Computation Results for Slope Element B

As shown in the upper right-hand corner of Figure 10A-11, this analysis results in an estimated annual average erosion rate of 42 tons/acre/year. Again using the "File" and "Save As" menu entries, this analysis is saved in the "Highly Disturbed Land" folder.

Since slope element C is very similar to slope element B, the just-completed analysis for element B may be used as the staring point for element C. The only difference between the two analyses is the number and length of the slope segments; thus, the “Topography” tab is clicked. Since element C has four segments, the “+” button above the segment numbers is clicked in order to open up a fourth line. Next, a grade of 25% (4H:1V) is entered in the “Steepness” column along with a total cumulative distance of 60 feet. Before finalizing the analysis, a distance of 42 feet is entered for the third segment.

As shown in Figure 10A-12, this analysis results in an average annual erosion rate of 74 tons/acre/year. This analysis is then saved under a new file name in the “Highly Disturbed Land” folder.

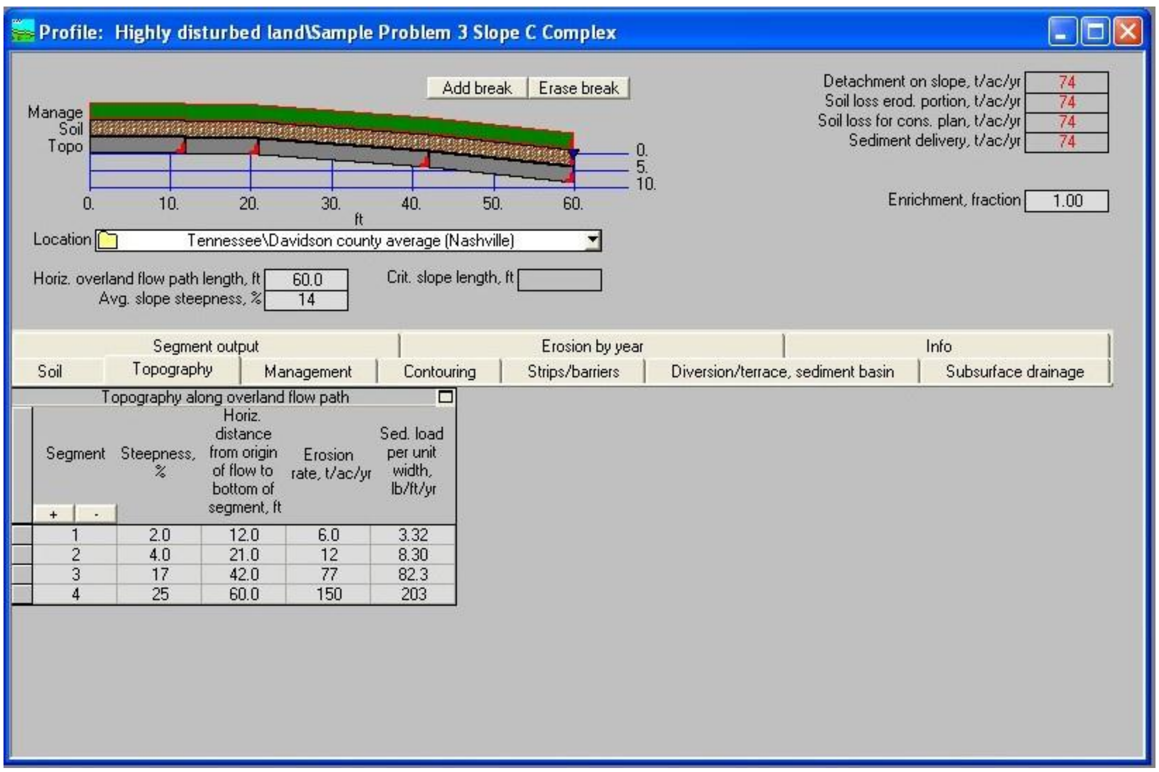


Figure 10A-12
Computation Results for Slope Element C

Step 4: Compute the Expected Annual Sediment Load

The results of the RUSLE2 analysis may be summarized as follows:

Slope element A: $68\ tons/acre/year \times 0.532\ acres = 36.2\ tons/year$

Slope element B: $42\ tons/acre/year \times 1.242\ acres = 52.2\ tons/year$

Slope element C: $74\ tons/acre/year \times 1.745\ acres = 129.1\ tons/year$

Slope element D: $81\ tons/acre/year \times 0.828\ acres = 67.1\ tons/year$

Assuming that all of the sediment eroded from the site is transferred through the side ditches to the sediment basin, this will result in a total average sediment inflow of 284.6 tons/year. It is likely that some deposition of sediment will occur in the side ditches, particularly for small rainfall events. Thus, this assumption is somewhat conservative, which will help ensure the effectiveness of the design.

Step 5: **Determine Maintenance Needs of the Sediment Basin**

It was determined in Step 2 that an area of 4.348 acres is to be served by the sediment basin. As described in Section 10.08.2, the volume of a sediment basin should be based upon allowing 134 CY per acre of area served, with half of that volume being in the "wet" storage pool. Further, sediment removal from the basin will be required once the accumulated sediments occupy half of the wet storage volume. In other words, the basin will require maintenance once the accumulated sediments amount to one-fourth of the total sediment storage volume. This may be computed as:

$$4.348\,acres \times \frac{134\,CY}{Acre} \times \left(\frac{1}{4}\right) = 145.7 \text{ CY}$$

Step 6: **Convert RUSLE2 Results from Tons/Year to Cubic Yards**

Unfortunately, the output from RUSLE2 is in terms of tons/year while the design of the sediment basin is based upon cubic yards. To finish the problem, it is necessary to determine a conversion between tons and cubic yards for the sediments which would be produced from the site. However, this conversion can be very complicated, as the specific gravity of the solids can vary based upon the parent material of the sediment and void ratios can vary based upon the size and gradation of the material as well as the means by which it was deposited. To simplify this problem, approximate average values are assumed for these parameters. Thus, the specific gravity of the solids is assumed to be 2.65 and the void ratio is assumed to be 40% (or 60% solids). Using these assumptions, the unit weight of the sediment may be computed as:

$$2.65\left(\frac{62.4\,lbs}{CF}\right)\left(\frac{27\,CF}{CY}\right)\left(\frac{1\,ton}{2000\,lbs}\right)(60\%) = 1.34 \text{ tons/CY}$$

Step 7: **Determine the Expected Frequency of Maintenance for the Basin**

Using the sediment weight determined in Step 6, the sediment inflow to the sediment basin may be computed as:

$$\frac{284.6\,tons}{year} \times \frac{1\,CY}{1.34\,tons} = 212.4 \text{ CY/year}$$

Thus, the average length of time required to fill up half of the "wet" storage pool of the basin may be computed as:

$$\frac{145.7\,CY}{212.4\,CY/year} \times \frac{52\,weeks}{year} = 36 \text{ Weeks} \approx 8 \text{ months}$$

Given the conservative assumptions in this analysis, and the expected duration of the proposed construction, it is likely that the basin will require maintenance only once, at the conclusion of the project.

CONCLUSION:

A number of conservative assumptions were made to simplify the solution of this problem. At some point in this project, the travel lanes and shoulders will be paved, greatly reducing the quantity of sediment produced. In addition, it is very likely that temporary or permanent seeding will occur on the side ditches, further reducing the expected erosion rates. RUSLE2 offers the capability of modeling the variations in erosion rate which would occur as the character of the ground surface changes during construction. However, that type of analysis can become quite complex and is beyond the scope of this problem. As has been shown in this problem, this more complex analysis would often not be required in practice.

10.09.3 GLOSSARY

The following list of terms is representative of those used in erosion prevention and sediment control practices. The terms may not all be used in the chapter text; but rather are commonly used by engineers, scientists, and planners.

BEDLOAD – Sediment or other material which is transported by flowing water along the bed of a waterway, by sliding, rolling, or bouncing.

BENCH TERRACES – Horizontal shelves placed at intervals on a steep slope which reduce erosion by preventing large concentrations of runoff from forming on the slope.

BEST MANAGEMENT PRACTICES (BMPs) – The application of appropriate control measures, project scheduling, and maintenance activities to prevent erosion and sedimentation on a construction site.

BUFFER ZONE – A continuous area of dense perennial vegetation, either existing or planted, which is left undisturbed along the edge of a stream, lake or other water body. These zones intercept sheet flows in order to reduce flow velocities and to filter sediment or other pollutants from the runoff before it enters the water body.

CHANNEL – A long narrow depression associated with a waterway which is shaped by the concentrated flow of a stream and conveys the ordinary flows.

CHANNEL EROSION – The dislodging of sediments or other materials from the bed or sides of a waterway channel due to shear stresses imposed by large flows.

CHANNEL LINING – Materials such as vegetation, machined riprap or geotextiles which protect a waterway from erosion during high flows.

CLEARING AND GRUBBING – A process under which land is prepared for grading by the removal of trees, herbaceous vegetation, roots, large rocks and any other objectionable materials.

COFFER DAM – A temporary structure used to exclude or divert water from an area where construction must be done in the dry.

CONCENTRATED FLOW – A flow condition in which the velocity and momentum of the flow are limited to a defined space. This could include flows in a rill or waterway as well as a flow jet entering a larger water body.

CONSTRUCTION PHASING –The practice of dividing a construction site into sections so that clearing and grubbing can be done one section at a time. This serves to limit the area exposed to increased erosion risks at any given time.

CONTROL MEASURE – An arrangement, structural or otherwise, which can be implemented on a construction site either to prevent erosion or to intercept eroded sediments before they are transported from the site.

<u>COUNTY SOIL SURVEYS</u> – Publications, usually produced by the NRCS, which provide detailed information on the properties of the soil types found in each county of the state. These surveys include aerial mapping which may be used to identify the soil types present on a specific site.

<u>COVER (GROUND OR VEGETATIVE)</u> – Materials on a ground surface, either existing or placed, which serve to prevent erosion. These materials could include existing vegetation, seeded grasses, mulch or erosion control blankets.

<u>CRITICAL POINT</u> – The point on a ditch or stream within the limits of a construction project where the design flow rate for sediment control will be the greatest. Usually, this will be the downstream point at which the waterway crosses the construction limits; however, it may also be any point within the project limits where the waterway discharges into a stream, wetland, or other water body.

<u>DEPOSITION</u> – A process in which sediments which have been eroded from one location accumulate in a new location.

<u>DETENTION</u> – The collection of stormwater runoff into a surface reservoir so that the water can be released at a reduced rate. Detention will typically be used to reduce the peak discharge from developed area to a rate that is equal to or less than the pre-developed condition (c.f. – Retention, Extended Detention).

<u>DEWATERING</u> – An operation in which water from rainfall, groundwater seepage or any other source, is removed from an excavated area within a construction site, usually by means of pumping.

<u>DEWATERING STRUCTURE</u> – A device, such as an open basin or bag, which is used to separate sediments from the effluent pumped during a dewatering operation.

<u>DISTURBED SOIL</u> – Soil which has been changed from its natural state by the clearing of vegetation or by manipulation with earth moving equipment.

<u>DISTURBED AREA</u> – Area of the site to be cleared, graded, or excavated during the life of the project. Defined as the total area inside the slope lines plus the area inside a 15 foot wide strip of land immediately adjacent to the slope lines.

<u>DITCH CHECK</u> – A temporary dam constructed across a swale or waterway which discourages erosion by reducing the velocity of the flowing water. Ditch checks can also control sediment by causing sediments to settle out or by providing a filtration capacity.

<u>EPHEMERAL STREAM</u> – A natural watercourse which carries flow only for short periods of time and as the result of precipitation events (c.f. – Intermittent Stream, Perennial Stream).

<u>ERODIBLE SOILS</u> – Soils which have an especially high potential for erosion due to the type of soil, slope or slope length.

<u>EROSION</u> – The process by which a ground surface is worn away due to the detachment of soil particles by external forces such as rain or wind.

EROSION CONTROL BLANKET – A temporary degradable rolled erosion control product composed of processed natural or polymer fibers mechanically, structurally or chemically bound together to form a continuous matrix to provide erosion control and facilitate vegetation establishment.

EROSION PREVENTION AND SEDIMENT CONTROL (EPSC) PLAN – A staged set of site plan sheets and construction notes which illustrate and explain the erosion prevention and sediment control measures to be used on a roadway project. These plan sheets are an integral part of the overall Stormwater Pollution Prevention Plan (SWPPP) for a project.

EROSION PREVENTION – Applying planned control measures in order to prevent or slow the increased erosion which can result from man-made changes to the landscape.

EXCEPTIONAL TENNESSEE WATERS – Surface waters of the State of Tennessee which are: a.) designated by the Water Quality Control Board as Outstanding National Resource Waters; b.) waters that provide habitat for ecologically significant populations of certain aquatic or semi-aquatic plants or animals; c.) waters that provide specialized recreational opportunities; d.) waters that possess outstanding scenic or geologic value; or e.) waters where existing conditions are better than current water quality standards.

EXTENDED DETENTION – The detention of stormwater flow in a manner that releases the water slowly over a period of days through a drawdown device. This allows for improved water quality by providing time for sediment and other pollutants to settle out.
(c.f. – Retention, Detention).

FINISH GRADING – Construction activity which establishes the final elevation of the site after excavating or filling in conformance to the grading plan (c.f. – Rough Grading).

GABION BASKETS – Rectangular boxes made of woven steel wire which is filled with stone to form large, heavy units.

GULLY EROSION – A form of erosion which creates relatively large, deeply incised channels, and which occurs when small erosion problems, such as rill erosion, are left unchecked (c.f. – Rill Erosion, Sheet Erosion).

IMPAIRED WATERS – Any segment of the surface waters of the State of Tennessee which has been listed by the Department of Environment and Conservation-Water Pollution Control Division, as having insufficient water quality to support its classified use, due to siltation (silt and sediment), habitat alteration, or other factors. This list is referred to as the Section 303(d) List.

INTERMITTENT STREAM – A natural watercourse which has flowing water during certain times of the year, when groundwater provides stream flow, or following rainfall events (c.f. Ephemeral Stream, Perennial Stream).

INTERRILL EROSION – Sheet erosion which occurs on the relatively flat ground surface between rills.

ISOERODENT LINE – A line placed on a map to denote equal potential for erosion due to rainfall impact in an average year. This line measures only the rainfall component of erosion; other factors such as slope, land use, etc. are considered separately.

MULCH – A protective layer of straw or other materials applied to exposed soils, which usually have been seeded with grasses. These materials protect the soil surface from of raindrop impact, encourage germination of the seed, and suppress weed growth.

NRCS – The Natural Resources Conservation Service, a branch of the United States Department of Agriculture.

OVERBANKS – The portion of a natural or artificial waterway above the banks of the channel which will convey flood flows when the channel capacity has been exceeded.

OVERFLOW WEIR – A depressed area provided at the middle of the crest of in-stream sediment control devices, such as rock silt screens or rock check dams, which provides an opportunity for high flows to pass over the structure without causing erosion where the ends of the structure intersect the existing ground.

OVERLAND FLOW – Sheet flow beginning from the point at the top of watershed where runoff begins to the point at which flows begin to concentrate.

PERENNIAL STREAM – A natural watercourse which has flowing water year-round during a typical year. Also known as a "live stream" (c.f. Ephemeral Stream, Intermittent Stream).

PERIMETER CONTROLS -- A barrier established around a construction site which retains sediments on-site by filtering runoff by or diverting it to a sediment trap and which prevents off-site run-on from entering.

PERMANENT SEEDING – The application of topsoil, seed, fertilizer and an appropriate mulching material to a finished grade in order to establish a permanent vegetative cover.

PERMEABILITY – The ease with which water can penetrate or pass through the soil or a layer of subsoil.

RAINDROP EROSION – A dislodging of soil particles which occurs as the soil surface is bombarded by raindrops.

RAINFALL INTENSITY – The rate at which rainfall occurs during a storm event. In English units, rainfall intensity is measured in inches per hour.

RECEIVING WATERS – Surface waters, such as ditches, streams, wetlands, etc., to which runoff from a construction project will directly or indirectly drain.

RETENTION – The collection of stormwater flows from a site into a surface reservoir consisting of a permanent storage pool and an overlying zone of temporary storage. The stormwater retained in the permanent pool of the reservoir will be released through groundwater infiltration or evaporation. This will provide significant water quality improvements by reducing the discharge of sediment, metals, floatable debris, and vehicle fluids (c.f. – Detention, Extended Detention).

RETURN PERIOD – The average number of years between two rainfall or flood events of the same magnitude. Return period is the inverse of the probability of an event.

REVISED UNIVERSAL SOIL LOSS EQUATION (RUSLE) – An equation, along with the accompanying methods to estimate the equation parameters, which may be used to estimate the average annual erosion from a site in terms of tons per acre per year.

RILL EROSION – A form of erosion which creates small but well-defined channels in the soil. These small channels begin to form where sheet flow begins to concentrate in the low spots of irregular surface contours, and are usually only a few inches deep (c.f. – Sheet Erosion, Gully Erosion).

ROUGH GRADING – Construction activity in which existing land grades are brought into approximate conformity with the grading plan by means of excavation, filling and compaction (c.f. – Finish Grading).

RUNOFF – Water from rainfall or snow melt which is not absorbed into the ground; but rather flows across the surface of the land and is collected into streams, lakes or other surface depressions.

RUNOFF COEFFICIENT – A measure of the amount of total rainfall from a storm event which will become runoff, usually expressed as a percentage of the rainfall depth. Also considered the as the ratio of rainfall that is not absorbed, by the total amount of rainfall that falls during a storm.

RUN-ON – Overland stormwater flows, in either sheet or shallow concentrated form, which would flow onto a construction site from upstream areas.

SEDIMENTATION – The gravity-induced settling of soil or other particles which have been transported by water or wind. Forming or depositing sediment.

SEDIMENTS – Fragments of soil which come have been eroded from the ground surface or from rock and are transported by water, wind or other means. The product of erosion.

SEDIMENT CONTROL – The use of Best Management Practices to capture eroded sediments in construction site runoff so that the water flowing from the site will be relatively sediment-free.

SEDIMENT-IMPARED WATERS – See “Impaired Waters”

SEDIMENT LOAD – The quantity of sediment, measured either by weight or by volume, transported by a given flow of water. This may range from large particles which are transported only by high flows to finely divided silt or clay particles which may settle out over long periods of time.

SEDIMENT TRAP – A temporary reservoir or excavated pool which collects stormwater runoff and allows sediments to settle out before the water is discharged.

SHEET EROSION – A form of erosion in which soil particles are transported by the flow of water as it runs off the land in a sheet flow condition (c.f. – Rill Erosion, Gully Erosion).

SHEET FLOW – A flow condition in which water moves across the ground surface in a thin sheet. This is usually the first step in the process of forming runoff and can persist only for a short distance before water is concentrated into ground surface irregularities.

SLIT-FILM WOVEN GEOTEXTILE – A fabric used in certain types of silt fence composed of thin strips of polyester or polypropylene woven together at right angles to form a relatively impermeable barrier.

SLURRY – A mixture of a liquid, usually water, and any type of insoluble particles, such as clay or other sediments.

SOIL – The unconsolidated mineral or organic material on the surface of the earth that serves as a natural medium for the growth of land plants. It consists of materials near the earth's surface that, in contrast to the underlying parent material, have been altered by the interactions of climate, relief, and living organisms over time.

SPECIAL DITCHES – Roadway side ditches which have grades independent of the roadway profile grade. Where special ditches are used, the roadway cross section will vary longitudinally (c.f. – Template Ditches).

STABILIZED – A condition under which soil is held in place by an enduring cover of vegetation, mulch or other material such that it will resist erosion by rain, flow of water, wind, vehicular traffic or any other factor.

STAGING (OF AN EPSC PLAN) – Dividing an EPSC Plan into different parts so that the structural BMPs specified for each part will address the changing erosion prevention and sediment control needs of a project as it progresses.

STAIR STEP GRADING – A grading practice in which a steep slope is formed into a series of horizontal shelves which alternate with nearly vertical faces in order to reduce erosion by discouraging the formation of concentrated flows.

STEEP SLOPE – For the purposes of NPDES permitting, considered a natural or constructed slope with a grade equal to or greater than 35 percent.

STORMWATER POLLUTION PREVENTION PLAN (SWPPP) – A site specific written plan, developed in order to ensure as much as possible that stormwater discharges from a construction project site will not pollute the surrounding natural water resources. This plan must identify all potential sources of pollution associated with the project, including sediment. It must also specify the structural and operational practices to be used to prevent pollution and assure that these practices will be carried out.

SURFACE ROUGHENING – A process by which a slope is provided with an irregular surface by any of a number of means in order to discourage erosion and the formation of rills.

TEMPLATE DITCHES – Roadway side ditches based upon maintaining a consistent roadway cross section along a segment of the roadway. The grades of template ditches will be equal to the roadway profile grade (c.f. – Special Ditches).

TEMPORARY SEEDING – The placement of mulch, fertilizer and seed for rapidly growing annual grasses, small grains, or legumes in order to control erosion on disturbed areas that will require subsequent earth-moving activities at a later time.

TOTAL MAXIMUM DAILY LOAD (TMDL) – The maximum amount of a pollutant that a water body can receive in a 24-hour period and still meet water its quality standards. The definition of a TMDL includes a program to allocate the amount of the pollutant which may be discharged from various point sources into the water body.

TOP SOIL – The layer of rich soil which may be found at the surface of an undisturbed, natural site. This soil usually contains the nutrients necessary to support the growth of desirable vegetation.

TURBIDITY – Reduced clarity in water (or other liquid) caused by suspended solid matter, which usually will settle only very slowly. These small solid particles (generally invisible to the human eye) can cause the water to be murky, cloudy, hazy, and in some cases opaque.

TURF REINFORCEMENT MAT – A geotextile lining consisting of two or more UV-stabilized plastic grids which contain a matrix of large fibers used to protect the bottom and sides of a newly constructed ditch while vegetation is being established. These materials will remain in place after vegetation has been fully established and will contribute to the overall erosion resistance of the ditch lining.

UTILITY RELOCATION – A process by which existing utilities and their associated easements are moved or replaced in order to avoid conflict with a proposed roadway construction project.

WATERS OF THE STATE – Any surface or ground water that is contained in, flows through, or borders on Tennessee, except for certain private waters that do not join with natural surface or underground waters.

WATERWAY – Any natural or constructed stream, river, creek, ditch, canal, etc. in which water flows either continuously or intermittently.

WOODY RE-VEGETATION – The replacement on a permanent basis, either in the existing location or in a new location, of trees or shrubs which are affected by a construction project.

WOVEN MONOFILAMENT GEOTEXTILE – A fabric used in certain types of silt fence composed of a single polyester or polypropylene filament woven together at right angles to form a relatively permeable barrier.

10.09.4 REFERENCES

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10.09.5 ABBREVIATIONS

AASHTO – American Association of State Highway and Transportation Officials
ARS – Agricultural Research Service
ASCE – American Society of Civil Engineers
BMP – Best Management Practice
CWA – Clean Water Act
EC – Erosion Control
EGEM – Ephemeral Gully Erosion Model
EPA – Environmental Protection Agency
EPSC – Erosion Prevention and Sediment Control
FHWA – Federal Highway Administration
HEC – Hydraulic Engineering Circular
MUSLE – Modified Universal Soil Loss Equation
NOI – Notice of Intent
NOT – Notice of Termination
NPDES – National Pollutant Discharge Elimination System
NRCS – Natural Resource Conservation Service
NURP – Nationwide Urban Runoff Program
PAM – Polyacrylamide
PLS – Pure Live Seed
RUSLE – Revised Universal Soil Loss Equation
SCS – Soil Conservation Service
STR – Structure
SWMM – Stormwater Management Manual
SWPPP – Stormwater Pollution Prevention Plan
TDEC – Tennessee Department of Environment and Conservation
TMDL – Total Maximum Daily Load
TNCGP – Tennessee Construction General Permit
USACE – United States Army Corps of Engineers
USDA – United States Department of Agriculture
USGS – United States Geological Survey
USLE – Universal Soil Loss Equation
WEPP – Water Erosion Prediction Project